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Chairman Larry Penley
Arizona Board of Regents
2020 N. Central Avenue, Suite 230
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Dear Regent Penley:

Attached are reports on my individual performance incentives for FY19. This year's reports focused heavily on the future of NAU and our contribution to critical initiatives such as Achieve60AZ, increased educational attainment in Arizona, and alignment of educational opportunities for individuals with career goals and Arizona's economic needs. These performance measures advance NAU in both key academic areas and strategic enrollment management planning.

I have also attached an update on my multi-year goals. This is the second year in this cycle and while we still have progress to make in three key areas, each connected to enrollment, I am particularly pleased with our institutional progress in freshman retention this year. As our student population continues to increase in size and NAU maintains its commitment to access and diversity, student retention remains an ongoing challenge which requires institution-wide focus and attention. As reported in my 2018 Operational and Financial Review, NAU's freshman retention dropped last year. After coordinating our student success initiatives campus-wide during the 2017-2018 academic year, we are seeing good progress in our freshman retention and look forward to our final report in this year's OFR. This priority area, along with persistence to graduation, is certainly top-of-mind and integral to all of NAU's overall student success efforts in strategic planning, strategic enrollment planning, and administrative reorganization.

I look forward to a collaborative year among the Enterprise Executive Committee and ABOR leadership and appreciate the time that has been spent understanding what makes NAU a unique place and our vision for advancing this institution. The potential in Arizona is great and the leadership, faculty, and staff at NAU are dedicated to improving educational attainment, quality of life, and economic prosperity in Arizona.

Sincerely,

Rita Hartung Cheng
President

Attachments:

- Transmittal Letter (page 1)
- 2018-2020 Multiple-Year Goals Update (page 3)
- Badging and Credentialing Report (page 7)
- Phase I of Enrollment Modeling Report (page 17)
- References and Attachments (page 28)
    - Badging sub-attachments:
        - #1 Hannover-BLS Analysis
        - #2 Computational Thinking
    - Enrollment sub-attachments:
        - #1 SEM Committee Membership List
        - #2 ABOR 2012 Pledge Analysis
        - #3 ABOR 2012 Pledge Analysis PPT
        - #4 Spring 2018 Pledge Analysis
        - #5 Sensitivity Analysis of Enrollment Mix 1
        - #6 Sensitivity Analysis of Enrollment Mix 2

2018-2020 Multiple-Year Goals Update

Northern Arizona University has engaged in significant planning and strategic visioning over the last two years to serve a broader population of students through an improved system of services, while remaining focused on the personalized relationships that define our institution's reputation. As an organization, NAU continues to be student-centered, focusing on student, faculty, and staff engagement at an individual and personalized level. As NAU has developed, expanded, and created a more vibrant Flagstaff campus community, developed multiple educational delivery models throughout the state, and further built our online enterprise, we continue to reflect on this priority when evaluating our programs and practices and when launching new initiatives that will lead NAU into the future.

The State of Arizona has set aggressive goals for educational attainment through the Achieve60AZ initiative. The ABOR 2025 metrics support the strengths of each university in contributing to the achievement of this effort to improve the lives of individuals with enhanced educational opportunities, as well as the economic vitality of the state with a diversified workforce. I appreciate the collaborative nature in which NAU's metrics were developed, and while there are aspirational areas for the institution, I believe they are the right targets, not only for NAU, but also for the State of Arizona. I am confident that we can continue to grow our enrollments while maintaining a personal experience for our students, grow our research enterprise, and remaining focused and strategic in our target areas.

These goals do not come without challenges, which we have discussed throughout the last year. Several of these challenges prompted the at-risk assignment for this year related to an overall strategic enrollment management plan and model which considers financial impacts for NAU. These goals have also driven critical administrative reorganization measures to allow our team to work collectively on enrollment management, student affairs, and campus life while recognizing that our university has matured to a size and complexity that requires distinct attention in each area. This reorganization included the addition of a new Vice President for Student Affairs separate from our Vice President for Enrollment Management. This new structure also allowed us to reassign important campus administrative functions to better align related areas and foster greater collaboration. We have hired a new Dean of Students who brings many years of experience at similar institutions to NAU.

The enrollment goal is reflected in NAU's strategic enrollment management plan, and, while we will be challenged to meet the 2020 target, this contribution to the overall educational attainment for Arizona has driven important system discussions related to mission, as well as critical campus discussions regarding the best delivery model to reach students. A multi-year strategy has been developed with the 2025 ABOR metric as the pinnacle achievement and NAU has developed annual targets to meet this longer term goal. The freshman retention goal in particular will require NAU to support our student success initiatives at the university-wide level that individuals have verbally committed to and in which every NAU employee takes great pride. The years ahead will be challenging, as we remain committed to the ongoing expansion of our diverse student population to continue to reflect the diversity of Arizona's population and provide Arizona residents access to an affordable, high-quality higher education. Achieving

these goals requires a university-wide commitment to implementation of the Customer Relations Management system we have adopted to support increased numbers of students with improved persistence and graduation outcomes.

Below is an update on the status of my multiple year goals. As I have said in almost every speech to the NAU campus, the communities we serve, and to the Regents, these numbers guide our decisions and resource allocation and drive us toward our goals. These goals also remind us that NAU is about the students, faculty, staff, alumni, donors, and supporters who make up our campus community and the stories behind each of their journeys. Our goals align with the overall goals for the State of Arizona, and while the interim timelines may be adjusted along the way, NAU will be a strong contributor to the ABOR 2025 metrics. I am proud of the progress we continue to make in each area, serving a greater number of diverse students and providing access to Arizona students and families. I continue to look forward to the future.

Freshman Retention:

- 2018: 73.5%
- 2019: 78.1% (preliminary data as of 7/30; final available in Fall)
- 2020 Goal: 78.0%
- 2020 Over-Attainment: 78.5%

Research Expenditures:

- 2018: $52.9M
- 2019: $58M (preliminary data as of 7/30; final available in January 2020)
- 2020 Goal: $40.8M
- 2020 Over-Attainment: $42.2M

Bachelor's Degrees Awarded:

- 2018: 6,042
- 2019: 6,300 (projected; final available in Fall)
- 2020 Goal: 6,431

Total Students:

- 2018: 30,704 (Fall 2017-FY18)
- 2019: 30,581 (Fall 2018-FY19)
- 2020: 30,100 (Fall 2019 projected as of 7/30; final available in Fall)
- 2020 Goal: 32,716 (Fall 2020-FY21)

Number of Degrees in High Demand Fields:

- 2018: 3,836
- 2019: 3,9500 (projected as of 7/30; final available in Fall)
- 2020 Goal: 4,146

Progress toward several critical university initiatives is below. The first measure represents enrollment management and the key role it has to the overall ABOR 2025 metric goals and to NAU's mission and financial system/structure. Developing an enrollment model with individual goals by student segment is critical to NAU's future campus planning, budgeting, and communications efforts. This campus-wide effort has allowed a broad range of department leaders to participate in the discussion of student enrollment, retention, and overall persistence to graduation and encouraged responsibility for goal attainment at a more comprehensive level. This effort also provided an opportunity to review our organizational structure that supports enrollment management, student affairs, and campus life and make necessary adjustments.

In order to address specific enrollment needs, we have developed and implemented targeted program offerings, particularly in graduate fields, and alignment of current certifications to existing professional masters degrees has launched us quickly into the arena of stackable credentials. Specific areas of growth include social work, psychology, school counseling, allied health fields, and more. Undergraduate transfer student enrollment has also been an area of emphasis. As part of the OneNAU initiative, we are revitalizing partnerships with key community college districts that have resulted in program growth in specific areas in Flagstaff, statewide, and online. While community colleges as a whole face enrollment challenges and our transfer student enrollment will require close attention, NAU's robust partnerships across districts and our programs that are responsive to student needs and workforce demands are helping to build on our strengths in this key area of enrollment.

Last year NAU underwent several stages of academic restructuring. This included hiring a Provost who brings significant experience with NAU's history and a strong vision for the future. New colleges and academic programs were approved by the Board to address both student population growth and Arizona's workforce needs. Furthering this effort is NAU's evaluation of the market to develop targeted non-degree credentialing, certification, badging, and targeted professional master's degree offerings and opportunities. This initiative has included developing an internal structure to support this sector of the university enterprise, including a platform for maintaining the related non-degree coursework and programs. In addition, a new Vice Provost and Dean of Online and Innovative Educational Initiatives has been hired, who brings extensive experience in the field of online program development and delivery, continuing education, badging, and microcredentialing. Restructuring this position into a Vice Provost role will ensure centralized and strategic collaborations with all areas of our academic affairs enterprise.

NAU has moved from a FY16 operating budget that was not structurally balanced by approximately $4M, after experiencing a $17M budget reduction from the state, to a balanced budget providing for investments in both physical infrastructure and faculty and staff salary adjustments. One-time funds were used to balance the annual budget in FY16 and many difficult decisions were required while we developed longer range planning, implemented operational efficiencies, and reallocated resources to areas of the organization that could produce additional revenue and aligned with the university's mission. We made these adjustments to minimize adverse impacts on our students. Building on our work in recent years when sound budget

practices and efficiencies were implemented, we have begun significant change management efforts in our business practices to improve the delivery of administrative services and to update our compensation policies. The service delivery component of our Organizational Growth and Effectiveness Initiative project will further improve the alignment of resources and skills to deliver the administrative and support functions in the areas of human resource, finance, and research administration. The compensation and classification component will modernize the structures, policies, and practices related to classifying jobs and managing pay for non-faculty positions. In conjunction with the enhanced enrollment strategic planning, these actions complement NAU's strategic visioning.

As we move ahead, I am confident in our direction as a university and look forward to updating the board on further progress on our ABOR goals.

Badging and Credentialing Report

Northern Arizona University (NAU) has a long and positive history of providing access, engagement, research, and stewardship to students, communities, and businesses throughout Arizona. In reviewing market research and through dialogue with our community partners, there is a recognized need for professional development through credit and non-credit educational programs, online short format courses and certifications, badging/digital credentialing, and stackable credentials which allow individuals to progress through a degree in a non-traditional path primarily focused on career progression.

NAU has engaged in short-format continuing education offerings through hosted-conference engagements, professional development offerings, and credit-bearing certificates. In support of institutional efforts to develop an implementation plan for non-degree offerings, as well as stackable credentials that could lead to a degree, a taskforce was established to investigate opportunities and next steps. The taskforce was co-chaired by the Chief Information Officer and the Dean for NAU Online & Innovative Educational Initiatives. The group was asked to evaluate market opportunities, explore partnership options, identify certificate pathways and options, investigate design models, and consider ideas beyond the scope of what the institution offers today.

An environmental scan to evaluate market trends was conducted with assistance from Hanover Research. Findings included review of demand data from JobEQ and the Bureau of Labor Statistics for education and training needed to support the top industries and occupational projections for high growth fields in Arizona (Attachment #1, Hannover-BLS Analysis), including healthcare and social assistance, retail trade, accommodation and food services, administrative and support positions, educational services, and construction.

Non-degree and continuing education offerings are provided in a variety of formats and modalities, including certificates, single course offerings, continuing education credits, badging, micro-credentialing, and the like. Determining the right mix of internally and externally developed content was a consideration during the review. Leveraging content expertise in areas of institutional strength has been a hallmark of institutional efforts to date. Programs launched include the following: a wind energy certificate, a web and mobile applications certificate, a data analytics certificate, and a certificate in leadership in criminal justice administration.

NAU has also taken non-traditional pathways begun by other partners and developed completion degrees in areas desired by the workforce. One particular example launching this Fall throughout the state with support from industry partners and national community college organizations is the Industrial Leadership 90/30 program. NAU collaborated on a federal grant with several southern Arizona community colleges and those in southeast Maricopa County who make up the Sun Corridor as they worked with construction and manufacturing industries to address their workforce needs. In partnership with the Arizona Advanced Technology Corridor, NAU has now developed a bachelor degree completion program in Industrial Leadership that serves as a transfer pathway from AAS programs awarded by Mesa Community College, Central Arizona College, and Pima Community College to meet the needs of the manufacturing industry in Maricopa, Pinal, and Pima counties. We are building on this program with a Career and

Technological District (West MEC) in the West Valley and Estrella Community College to articulate a full program from high school to community college to NAU that will begin recruitment this fall.

Adding expertise from external partners to increase scale and scope of offerings while also accelerating time to market is of benefit. Parallel efforts have been underway to expand new offerings with internal talent and content while also evaluating third-party options for tracking and recognizing credentials. We have contracted with Credly[i] and will use this platform to issue and manage open eCredentials (badges) for professional development, continuing education, and for-credit applications. Initial efforts have been taken with professional development and continuing education programs to develop our initial badging capabilities. NAU has developed an extensive array of professional development for our staff and such resources are scarce in our local community. This fall we are expanding access to these opportunities to our community partners, beginning with organizations in the Alliance for the Second Century, which include the City of Flagstaff, Coconino County, Coconino Community College, and Flagstaff Unified School District.

Beginning this fall, NAU is also launching a pilot program for credentialing/badging participation in student leadership and other co-curricular programs. Programs contributing to this pilot include the Office of First-Generation Initiatives, Peer Mentoring, Associated Students of NAU (ASNAU), and the Transfer Center. This will provide students the opportunity to enhance and extend their academic experience by earning micro-credentials that verify, validate, and attest that specific skills and competencies have been achieved in co-curricular experiences. Badges will be offered through one or more non-credit-bearing experiential learning activities and represented by a verifiable digital badge on a co-curricular transcript, via Credly, or other online platforms, such as LinkedIn and Handshake. This initiative will expand in Spring 2020 to include a competency badging program for all student employees as part of a comprehensive student employment training program. Students will earn competency badges in each of the National Association of Colleges and Employers (NACE) career readiness competencies[ii]. Our student employment program was recently recognized by the Career Leadership Collective as one of the most innovative career programs in 2019[iii], and credentialing our student employment training will continue a strong commitment to innovation in our Student Employment Initiative and ensure our students have the transferable skills necessary to compete in the workplace after earning their degrees. Student Affairs and ITS will continue strategic planning efforts to roll out microbadging opportunities for all students beginning in Fall 2020. In addition, we have initiated conversations with faculty groups and key campus constituents about creating badging opportunities that link to formal academic work and student activities. Areas that capitalize on existing program strengths and structure, such as sustainability and environmental sciences, are the initial focus of these efforts. Conversations are ongoing about development of linked badges, as this area has demonstrated impact and significant opportunity for growth[iv,v,vi].

Extension of Credly to for-credit academic programs to accommodate mastery of skills and/or knowledge will be put in place by the Provost and managed by the University Registrar as the next phase of implementation in this effort of developing a system and infrastructure for this initiative.

Important in this initiative was identifying certificates currently available in individual colleges, aligning those certificates to make stackable degree options possible, and improving the external marketing of certificates which have the potential for enrollment growth, as well as the launch of new certificates, badges, and credentials. Efforts to streamline existing certificates into graduate degree opportunities provide a stackable credential for those who wish to pursue their education in phases included the following:

- Aligning the Assistive Technology (GCRT) to the Master's of Educational Technology degree,
- Aligning the Public Management (GCRT) to the Master's of Public Administration degree,
- Aligning the Tribal Management (GCRT) to the Master's of Public Administration degree,
- Launching the new Criminal Justice Administration (GCRT) and aligning it with the Master's in Organizational Leadership.

Badging and credentialing at NAU will be overseen by the newly hired Vice Provost and Dean of Online and Innovative Educational Initiatives, although individual program components will be housed in the academic college or department of the badge or credential content. This position has been restructured to include the title of Vice Provost, indicating the university-wide academic scope of the position, and the new hire brings extensive experience in online education, badging, and microcredential program creation and management. We will continue to explore best practices in this area. For example, Madison College has developed outcome measures in their badging process to demonstrate alignment with industry interests. One of our next steps in expanding interest in this effort to a broader campus population is to invite individuals from Madison College to present on their successes, processes and challenges[vii].

BACKGROUND MATERIALS

Expanding the scope of our educational offerings to include badging and digital credentials is an institutional strategic initiative. Allowing students to demonstrate knowledge and earn recognition of these efforts through badging is becoming common currency in the professional world. Collaboration with colleagues across higher education who have successfully implemented these efforts will help us progress more expeditiously and an NAU taskforce was established to create connections, initiate dialogue and provide frameworks for moving forward. NAU has created an institutional governance framework for badging as a fundamental first step. Governance defines the policies and processes necessary to ensure accountability, transparency, and the value of digital credentials. Key areas of consideration included administration of digital credentials, establishing standards and leveling through an institutional taxonomy, defining alignment of credentials to industry standards, determining types of digital credentials, authoring, and expectations, and establishing levels of autonomy and authority for institutional engagement with digital credentials. These efforts have been successfully navigated within and across institutions and leveraging our higher education partners improves our success.

The Lumina Foundation's *Credential Framework*[viii] is another key resource and will be used to

guide our efforts. Understanding what learners know and are able to do as an outcome serves as the reference point for comparing levels of knowledge and skills. These competencies are the underlying elements of performance for badges, digital credentials, certificates, and degrees. Mapping these competencies allows an institution to define alignment across types of credentials and create pathways for students. Defining comparability, providing transparency across credential types and improving portability of credentials are all in the best interest of the student and the institution. Intentional credential design using the Lumina framework and governance guidelines are critical next steps for our journey into badging and digital credentialing (Lumina Foundation, 2015).

Identifying a partner for designing and hosting badges and digital credentials is also an important element and the taskforce reviewed options and held multiple engagements with Credly. Credly is a leader in digital credentialing platforms and partners with industry and higher education entities to create, issue, and promote digital credentials. Identifying a partner to provide assistance through strategic planning and implementation will assist in our ability to go to market in a more expeditious and intentional manner. NAU engaged Credly's services as a result of the task force work and evaluation.

Many Arizonans are returning to the classroom to develop new skills, but not all of them are seeking a formal credential from their learning experience. Helping community members throughout the state move up in or get back into the workforce is a valuable attribute of the NAU brand. By responding to industry requests for new or continued workforce training, NAU maintains the reputation of being responsive and helping to educate all of Arizona's citizens, regardless of their educational attainment goals.

Leveraging a third-party to jumpstart our workforce education initiative is an opportunity for NAU to expand its educational services and, in partnership with a known entity, enter into the professional development marketplace with minimal investment. NAU will offer non-credit, just in time, online workforce training courses and programs to serve continuing education and corporate training markets with high quality, instructor-facilitated courses. These courses prepare participants to enter into or advance in some of today's fastest growing career fields and also provide industry employers with professional development options to enhance the performance of current employees.

In keeping with NAU's commitment to contribute to Achieve60AZ attainment goals, a partnership of this type accomplishes the following:

- Provides another venue for NAU to affect labor market needs through increased certifications and training.
- Increases NAU's reputation as being responsive and accessible to educating all of Arizona's citizens, regardless of their educational attainment goals.
- Builds NAU's connection to local community members throughout the state who want to move up or get back into the workforce.
- Expands NAU's contribution to Arizona's efforts for improving the completion of credentials and certificate programs that boost the prosperity of individuals in the State, which, in turn, positively impacts the Arizona economy.

By collaborating with a third-party partner, NAU will be able to quickly expand its offerings of online courses that are convenient, comprehensive, and affordable and that allow students to learn when their schedule permits—starting anytime, working at their own pace, and completing at an accelerated pace. Selecting a partner who provides short-format, non-degree continuing education offerings aligned to the technology industry, with a specific focus on competencies required for in-demand jobs, will provide us with an opportunity to build on our existing offerings while meeting the demands of students and employer partners who need specifically-skilled employees.

The technology industry has been selected as a first area of priority, as competition for skilled IT resources is increasing. The digital skills gap is already hampering digital transformation at 54% of companies. And that gap is widening. Korn Ferry's research[ix] predicts that by 2020, the technology, media, and telecommunications (TMT) industries may be short more than 1.1 million skilled workers globally. Microsoft, Cisco, Amazon, Google, Salesforce, and other companies have reported first-hand that they are constrained by the inability to hire qualified skilled staff to execute their business plans. It is predicted that the U.S. will be hit hardest by the talent shortage, losing $435.69 billion in unrealized economic output—or 1.5% of the whole U.S. economy. By 2030 that deficit may reach 4.3 million. This concern cuts across all sectors, as companies struggle to find educated and workforce-ready digital talent[x].

The popular literature underscores unmet workforce needs and extra-curricular skills development in college graduates[xi]. Some universities are turning toward certification programs that enrich traditional undergraduate and graduate learning to ensure students emerge from programs job ready. Moreover, technology leaders are looking to diversify their portfolios of technology skillsets as they digitize their businesses and play a more active role in driving institutional strategies. Liberal arts students and graduates of other fields who have augmented their formal learning with technical skills are highly sought to fill roles traditionally held by MIS, CS, and IT graduates (Attachment 2: Computational Thinking).

The following skillsets are of interest to our NAU Information Technology Systems Division and our corporate partners have identified similar resource gaps:

- Artificial Intelligence and Machine Learning (Microsoft, Google, Amazon)
- Data Center Certifications (Microsoft)
- Virtual Reality (Microsoft)
- Salesforce CRM/SRM
- Amazon Web Services Cloud
- Google Cloud
- SAP Terp 10
- Microsoft AZURE cloud
- Internet of Things
- Cisco Networking
- Information Analytics
- Adobe Creative Suite
- Design Thinking (IBM)

Responding to these IT skill needs allows for continued engagement with NAU's corporate partners who are interested in continued partnership to build a high quality workforce. Partners are at a variety of stages of professional development, from needs identification to providing their own courses/certifications. Existing corporate partners and directional discussions include the following:

- Microsoft Data Center Academy: NAU will apply to be recognized as a partner in the data center academy. Microsoft is interested in partnering with a 4-year institution and is especially interested in the NAU mission supporting Native American populations. If accepted, Microsoft provides the initial startup funding and equipment.
- Century Link: NAU and Century Link are co-developing a certificate program that may be unique for IoT practitioners and managers. A working document is under development.
- Cisco: conversations have been initiated, as Cisco partners closely with Century Link and there are additional synergies with discussions being held with other NAU partners.
- Salesforce: Salesforce offers 25 certifications through its free Trailhead platform in six areas—Administration, App Builders, Consultants, Developers, Architects, and Specialist.
- Amazon Web Services: Amazon offers free online training. For higher education special programs, Amazon requires faculty to adopt a curriculum in exchange for free access to AWS for educational purposes. NAU is exploring opportunities to partner on delivery/engagement with these offerings.

While developing a suite of non-degree offerings in-house may be a desired future-state outcome, we see an opportunity to meet the needs of our communities more expeditiously by combining internally initiated offerings with quality offerings provided by a third-party provider. An evaluation of providers and associated offerings has been completed for several potential partners. These reviews included product demonstrations, enrollment in course offerings, and subsequent evaluation of content and student experience. Additionally, there is interest in identifying a partner who provides access to content that is industry-aligned and offers a new set of courses/programs that align with market demand and fills a gap in our current portfolio of offerings. Results from these reviews are provided below.

Potential Audiences:

- Traditional continuing education (CE) for Workforce Development across Arizona
- Staff and Faculty Professional Development—specifically technology related
- Current degree seeking student alternatively credentialed learning (ACL)

Potential Partners Reviewed:

- SimpliLearn[xii]
- PluralSight[xiii]
- MindEdge[xiv]
- UCertify (A Pearson group)[xv]

The four potential vendors listed above were reviewed from a field of dozens of possible partners, each with similar instructional approaches but with a variety of options for back-end student progress data and ability to map competencies across courses. These partners each offer some type of certificate for course completion and are aligned to industry certification. However, obtaining the industry certification requires passage of an assessment outside of the product offering. In addition to product demonstrations, nine NAU employees reviewed fifteen different courses based on areas of interest and content expertise. Users were asked to evaluate their experience based on content relevancy, user experience, course design, and engagement/learning. There was general consensus on content relevancy, course design and navigation, but users voiced concerns about interactivity and learner engagement. The preferred provider, of those reviewed, was differentiated based on the ability to select customized course content, pretests to gauge current level of competency, administrator dashboards to gain insights into learner engagement, and underlying data and analytics.

NAU is now prepared to take the next steps in defining an RFP for a compatible partner in this endeavor. The task force involved in this effort will be expanded to include the Vice Provost and Dean of Online and Innovative Educational Initiatives who will partner with the Chief Information Officer in issuing the RFP and recommending a partner.

In addition to completing an environmental scan to determine labor market demand and workforce needs and establishing the balance of internal versus external offerings, an evaluation of organizational structures that support non-degree offerings was completed. Institutions of higher education typically house non-degree offerings in a central unit focused on professional education, non-degree and/or continuing education offerings. The Continuing and Professional Education units at Arizona State University and the University of Arizona are examples of such organizational structure. NAU currently has a decentralized approach to offering continuing education, as there are limited offerings across units being provided currently. Moving forward with a more comprehensive institutional approach to non-degree/continuing education, badging, and micro-credentialing will require a structured approach for academic governance and operations. Creating an intentional portfolio of offerings and establishing the requisite academic and institutional operations requires a structural design that will support the success of the initiative.

In an effort to develop targeted non-degree credentialing, certification, and badging options to address workforce needs, NAU will include this focused area of continuing and professional education in its Online and Innovative Education unit reporting into the Provost. Continuing to build our institutional governance process as we expand in the non-credit bearing badging and credentialing area and begin to build our academic structure in the for-credit badging and credentialing area will position NAU to be a more dynamic participant in the continuing education/professional development space. The division will have academic and operational oversight for the strategic development and implementation of non-degree offerings across the institution. While there are ongoing institutional efforts to design and deliver certificate programs and accelerated pathways that complement degree offerings, there is an institutional need to organize an approach to delivery of non-degree/continuing education, badging, and digital credentialing. Establishing a unit that focuses on the academic and operational elements

required to successfully launch, maintain, and grow the NAU portfolio of offerings in this area is necessary for success. A centralized approach to offering continuing education/digital credentialing will also allow a more thorough inventory of existing offerings across units that involve a variety of approaches for delivery, student experience, payment, and information distribution.

NAU has actively engaged in efforts over the last year to develop and complete additional certificate offerings which have either recently launched or are preparing to launch. One such example is the Boundaryless undergraduate certificate in Innovative Thinking and Problem Solving. Designed to meet general education requirements, this certificate program uses innovative interdisciplinary coursework to give students from all majors a competitive edge in the job market by fostering innovative approaches to problem solving, with an emphasis on real world applications. Boundaryless is also developing badging opportunities to further expand the program's reach and impact.

We are also working closely with Mother Road Brewery to launch a Brewing Certificate Program. Currently, there is a lack of comprehensive training programs in the southwest for those working in the industry. The majority of certificates focus on the brewing process. This certificate would be a collaborative effort with departments across campus and currently includes faculty in Chemistry, Hotel and Restaurant Management, and Engineering. We are expecting a launch in Fall 2020.

Below is an overview of the highlights of recent efforts in launching new certificate programs:

Certificate Name	Launch Timeframe
Boundaryless Innovative Thinking and Problem Solving Undergraduate Certificate	Fall 2018
Web & Mobile Applications (Option for Master Computer Information Technology Program – competency-based)	January 2019
Data Analytics (Option for Master Computer Information Technology Program – competency-based)	Fall 2019
Higher Education Leadership Certificate (GCRT)	Fall 2019
Wind Energy Certificate (GCRT)	Fall 2019
Building Science and Sustainable Infrastructure (GCRT)	Fall 2019
Integrated Behavioral Health (GCRT)	Fall 2020 (pending NIH grant funding)
Financial Planning Undergraduate Certificate	Fall 2020
Cybersecurity Certificate (graduate; military focus)	Fall 2020

Brewing Certificate (undergraduate)	Fall 2020

In addition, NAU expanded several professional masters programs to meet workforce demand, including two programs affected by the closure of Argosy University. NAU added an additional cohort to both the Master in Clinical Mental Health Counseling and Master in School Psychology programs, both held at the NAU North Valley Campus in Phoenix. These programs began adding students in Spring 2019 to respond to student and workforce demand ahead of our planned schedule to begin additional cohort groups in Fall 2019. We have already increased these programs by more than 65 students. Responsive to the needs of Arizona's behavioral health shortage and the further impact to the workforce with the closure of Argosy University, NAU also responded by expanding its academic strategic plan to add a PhD in Clinical Psychology in order to train practitioners in psychology in Arizona. This program will begin, pending HLC accreditation, in Spring 2020. Planning is also underway to expand NAU's Master in Physician Assistant Studies by an additional ten students each year as soon as we are eligible to do so per our accrediting body, the ARC-PA. Application will occur in Fall 2020 with the goal of expanding Fall 2021. We have grown our Master in Social Work program by adapting our program to an online format and just this May 2019 an accelerated 1-year option was launched. The following professional masters programs are launching soon and will help further expand NAU's impact:

- Professional Master's Degree Programs:

Program Name	Launch Timeframe	Notes
Master of Public Administration – online modality	Fall 2019	Expanded access via online modality
Master of Civil Engineering (non-thesis)	Fall 2019	Industry/workforce oriented (previously thesis-only)
Master of Environmental Engineering (non-thesis)	Fall 2019	Industry/workforce oriented (previously thesis-only)
Master of Cybersecurity	Fall 2020	Military cybersecurity focus

NAU has developed long-standing industry partnerships that inform our traditional academic programs. These advisory groups, as well as participation with local, state, and national business organizations and chambers of commerce, have informed our current efforts to design skill-specific badges, certificates, and credentials to assist individuals in the workforce advance their careers. Similarly, these efforts also provide those wishing to re-enter the workforce the ability to update their skills in a timely manner. For some, this will be a progression toward an academic degree, while for others, this will be the post-secondary education necessary to support them in their goals. In all cases, this effort aligns with state and national efforts to increase the level of educational attainment of our citizens and, for NAU, it further diversifies our academic offerings consistent with our traditional mission of access and workforce preparation. With new leadership in the NAU unit of Online and Innovative Educational Initiatives, coupled with the

strategic vision of our new Provost, next steps are underway for implementation of badging and credentialing, including issuing an RFP for a partner and a for-credit component. Implementation of targeted professional masters degree offerings as outlined in the report has occurred and is on track for continued action, and NAU will continue to identify additional areas for expansion that align with our academic strengths and the needs of the workforce and our students.

Phase I of Enrollment Modeling Report

Northern Arizona University's student enrollment history provides a good reflection point, having experienced enrollment declines from 1996-2005, a leveling off period, and most recently, a period of growth, primarily in the undergraduate student population on the Flagstaff residential campus from 2009-2016. During this time of rapid undergraduate growth in Flagstaff, other student populations were largely unattended to, including graduate students at all campuses (other than the targeted allied health programs at the Phoenix Biomedical Campus), online, and statewide campus student enrollments. In 2017, NAU began the OneNAU initiative to eliminate operational silos, including enrollment strategic planning, and to build a comprehensive enrollment management strategic plan that encompassed all student populations, campuses, and learning modalities. NAU has implemented a customer relations management (CRM) system, Salesforce, to support the cross-unit collaboration and multi-campus/modality support systems necessary under the strategies adopted. The work of this campus-wide team has culminated in Phase I of our enrollment modeling project (Attachment #1, SEM Membership).

NAU's enrollment modeling included the engagement of EAB (formerly the Education Advisory Board) and an enrollment management consultant, Williams and Company, to assist in the review and categorization of our competitors, the evaluation of enrollment trends by student segment at NAU, regionally, and nationally, the evaluation of demographic data, and the reevaluation of annual enrollment metrics by student segment, with identification of responsibilities within the institution. Full reviews of demographic trends, state educational needs, and strategic initiatives to increase college-going and attainment rates—with a particular emphasis on NAU's capacity and success with Arizona students—have resulted in annual internal enrollment metrics by student segment that are attainable and reflective of current and developable institutional strengths. This model is adaptable through an annual reevaluation of trends and achievement of metrics to ensure additional outreach campaigns and student intervention strategies can be implemented as necessary through the use of our CRM.

Phase I of NAU's strategic enrollment management plan and new model is built on the foundation of a matrix of strategies, necessary resources, identified "owners/leads," desired outcomes, and start/end dates. Within these strategies, it is important to note the significant emphasis placed on retention of our undergraduate student population in addition to the growth strategies identified in this report. NAU remains committed to meeting the ABOR 2025 metric of 80% retention and this is in line with the "Culture of Care" identified by our faculty. This effort is supported by the CRM, academic course redesign efforts, multi-term enrollment and class scheduling, advising enhancements, and administrative restructuring to have a collaborative but distinct focus on enrollment and student services through two separate leadership positions. A full review of the one-year drop in the retention rate from Fall 2017 to Fall 2018 was conducted, which found that both students of color and high achieving white students were impacted. Strategies were implemented that have already shown positive impacts from Fall 2018 to Spring 2019. A renewed emphasis on overall persistence to graduation is included in this Phase I report as a key undergraduate enrollment strategy.

Market research, including a deep-dive by Hanover Research, was conducted to evaluate several target populations and academic program demand. This initial review of academic program

demand in the market has resulted in increased marketing of programs that NAU currently offers to increase student awareness of, and enrollment in, existing programs. Next steps in this process will include the Provost working with academic units to align additional market demands with NAU's strengths to advance the development of additional academic program offerings, particularly in online modalities.

Price positioning strategies were developed based on regional and competitor comparisons. Tuition structures are unique to the campuses and populations served and it is critical that they be considered individually. NAU continues to believe that maintaining the Pledge guaranteed tuition program for its residential Flagstaff undergraduate student population is an important differentiator in the marketplace for recruitment and retention of current students. NAU intends to continue this strategy, but will also continue to evaluate the program's effectiveness, as has been a consistent practice. In September 2012, a comprehensive review of the Pledge program was conducted and the results provided to the Business and Finance Committee emphasized the viability of the program in conjunction with maintaining sufficient university liquidity/reserves (Attachment #2, ABOR 2012 Pledge Analysis; Attachment #3, ABOR 2012 Pledge Analysis PPT). In Spring 2018, an internal analysis was completed during the tuition and fee setting process, which indicated that in the absence of the Pledge program, annual increases in tuition of approximately 3.25% would have been needed each year starting in FY12 to have resulted in the same estimated tuition revenue for FY19 (Attachment #4, Spring 2018 Pledge Analysis). In other words, an annual 1-2% increase in tuition rates applied to all students each year would not have brought in a similar amount of revenue. A more immediate emphasis is to adapt financial aid packaging as necessary within the context of the Pledge tuition program, given the projected similar or smaller incoming freshman undergraduate cohort. With over 40% of tuition and fee revenue being generated outside of the Pledge program, the ability to make adjustments each year remains.

There are two critical areas in tuition and fee setting where NAU must differentiate itself: graduate program fee differentiation and online tuition. These efforts have already begun. For graduate program fees, NAU's FY20 tuition and fee proposal included a number of program fee adjustments, especially in high demand and professional degree programs. This will continue to be an important part of future planning cycles. During the 2017 tuition setting cycle, NAU overhauled our online tuition structure that affected the 2017-2018 academic year and beyond. This included eliminating antiquated differences in pricing for online tuition which exist on residential campuses, such as residential vs. non-residential price variation and part-time vs. full-time status, that were not reflective of the current online market. Given the importance of online enrollment growth, this tuition restructuring was a critical first step prior to launching significant student recruitment. Finally, it should be recognized that a mix of resident/non-resident students is an important tuition and financial aid differentiator that results in significant variations in net tuition.

NAU has diversified its mix of resident/non-resident students from 80/20% in 2007 to a current 67/33% in Fall 2018. Additionally, NAU's true non-resident student population—those who are not Western Undergraduate Exchange (WUE) students who pay 150% of resident tuition—has grown within the non-resident mix. NAU anticipates continued growth in the percent of non-resident students within the total student population, and has enacted enrollment strategies to

achieve this enrollment blend within target states and internationally. (Note: in all years, NAU was still serving a greater total number of resident students than in 2007, but the population mix changed.) A preliminary sensitivity analysis of enrollment mix suggests that as the proportion of online students relative to on-campus students grows, net tuition revenue and the percent of net to gross tuition revenue increases. The same holds true for rebalancing among Pledge categories of instate, WUE, online, and non-resident enrollment students. A careful shift among enrollment groups over the coming years will ensure greater financial sustainability in our operational model (Attachment #5, Sensitivity Analysis of Enrollment Mix 1; Attachment #6, Sensitivity Analysis of Enrollment Mix 2).

Development of the Education and Partnerships Department at NAU continues. Individuals with some college coursework who have not completed a degree, as well as those looking for additional credentials beyond a bachelors degree in order to progress in their professional life, are built into our community campus and online models. Partnership agreements have been developed with specific companies and government entities to expand employee outreach and benefit communications, particularly with employers who provide significant tuition reimbursement opportunities. NAU is also finalizing an agreement with EdAssist, which provides 3rd party tuition reimbursement benefits to a significant number of companies nationally. Our partnership with EdAssist will expand outreach efforts in this competitive field of adult learners.

A final step in NAU's Phase I implementation includes issuing a request for information (RFI) to collect additional details on an online program management (OPM) system for our online education programs. This RFI is a responsible step in coordination with conversations among sister institutions to evaluate the components of service appropriate for an OPM model of delivery. This RFI will be issued in Fall 2019 with anticipated review of responses and information during the next academic year and an implementation model included in Phase II reports.

Further steps are anticipated, including additional enhancements of the Salesforce CRM capabilities, the addition of new academic programming, especially online and graduate program offerings, continued assessment of advising and student support programs, and ongoing review of our price positioning, recruitment, and marketing strategies and structure.

BACKGROUND MATERIALS

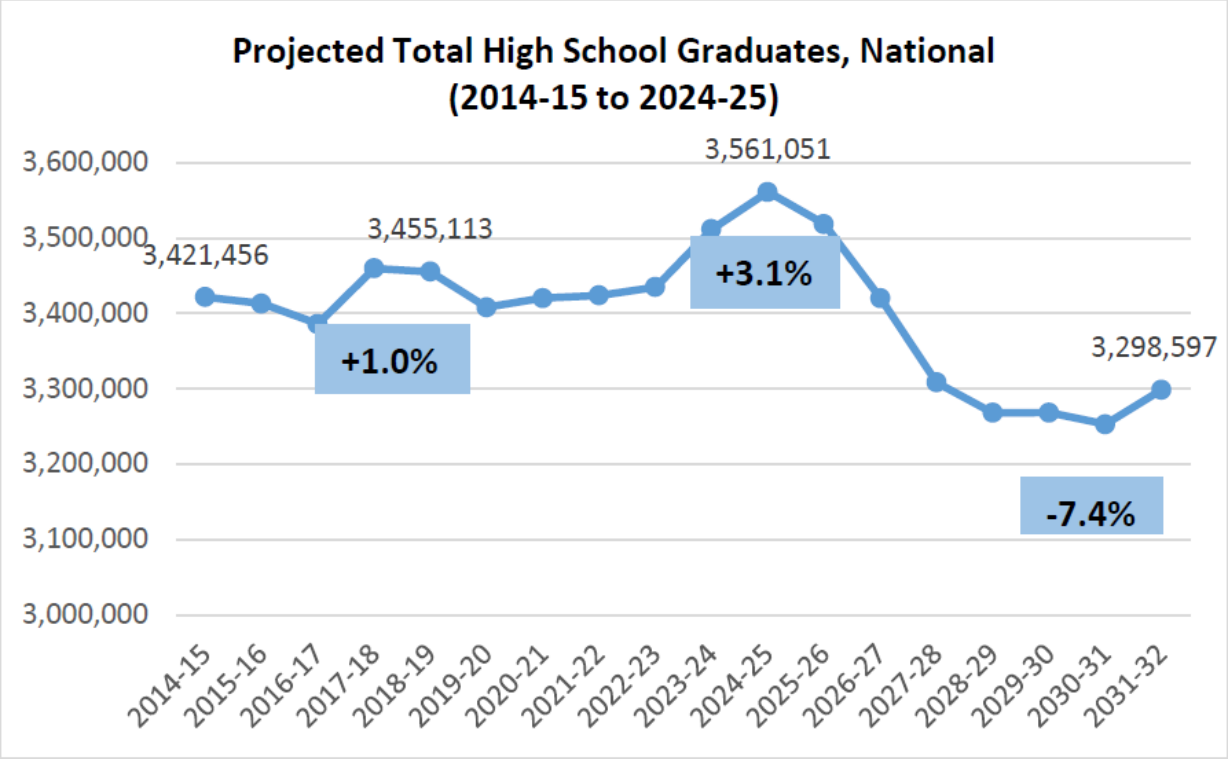
Developing and modeling enrollment strategies include addressing ABOR 2025 metrics, from the broad overall enrollment metric to key related metrics of graduate enrollment, graduate degrees awarded, high demand degrees awarded, and student retention. Enrollment growth is an individual student strategy for success as well as a state strategy for economic diversity and prosperity, as evidenced by statewide initiatives such as Achieve60AZ. As an institution with 67% Arizona resident students, NAU is a critical partner in the Arizona university system and the State of Arizona's mission and goals for an educated citizenry and workforce.

As Arizona's state investments in higher education have been challenged by the state fiscal

climate, it has become critical that our universities develop a public university financing system that is state supported but not state reliant. As an institution with a greater proportion of resident students, and a greater proportion of undergraduate students, assessing the financial impact of the mix of student enrollment, academic programs and degrees offered, and financial aid structure is critical and analyzed through the strategic enrollment management plan and this report. NAU has more limited external resources from grants, contracts, and donors, and has historically been more reliant on state resources. The state continues to be an important partner in NAU's overall budget model. However, recognizing that tuition now makes up approximately 42% of NAU's total revenue budget, a solid foundation has been adopted to address the mix of students and revenues through this strategic enrollment management model.

Phase I of NAU's enrollment and tuition model report addresses trend analysis, strategies, current efforts underway, and future steps as we continue to engage in comprehensive enrollment strategic planning by student segment through a campus-wide effort (Participants provided in Attachment 1). NAU's recent enrollment growth has relied on Flagstaff residential undergraduate students as opposed to all NAU enrollments. As a result, recent flat enrollment on the Flagstaff Campus and decline in the Flagstaff Campus entering freshman class impacted the overall NAU enrollment and budget projections. This report demonstrates a much greater diversified approach to NAU enrollment reflecting both external and internal factors.

High school graduates (HSG) are the main population from which traditional undergraduates are drawn. The Western Interstate Commission for Higher Education's (WICHE's) Knocking at the College Door (published December 2016, using private school actuals only through 2011-2012 and public school actuals through 2012-2013) is the most commonly cited source for HSG projections. As shown below, the number of HSG nationally are projected by WICHE to have been fairly steady from 2014-15 to 2018-19, to increase by 3.1% from 2018-19 to 2024-25, and to drop off sharply after 2024-25. Other reports with newer national HSG actuals show that the 2018-19 to 2024-25 increase may be lower than 3.1%.



(Data extracted from WICHE *KOTCD, 2016*)

EAB and other consulting groups have recently been using projections made by Nathan Grawe[xvi] to determine future trends in HSG and traditional undergraduate production in the United States. EAB has highlighted the following information based on Grawe's methodology:

- Arizona – A small increase of 2,700 four-year college-going students is projected from 2017-2026, with a steep decline thereafter, resulting in a 10% decline from 2017 to 2029.
- Arizona – A higher proportion of low-income households and higher than average-priced public and private institutions make it harder to attract students who can afford to attend.
- Region – Regional four-year institutions in Arizona, Hawaii, Nevada, and New Mexico are all projected to have a 10% to 19% drop in higher education institution (HEI)-going students from 2017-2029. (NAU is considered a regional four-year institution in Grawe's methodology).
- Public national HEIs (such as ASU and UA) may recruit students away from regional institutions to bolster tuition revenue.

NAU also reviewed both national and Arizona specific trend data on community college transfer student populations given that transfer students are also a significant feeder population. Nationally, the number of students who transferred from a community college to a university peaked in 2010 and has fallen every year through the last year of data (2016). In Arizona, information from the ASSIST Data Warehouse indicates that transfers to NAU peaked in 2015-2016 while transfers to the Arizona University System as a whole peaked in 2016-2017. Overall,

community college enrollment in Arizona has been declining since 2010, shrinking the pipeline of potential transfer students.

A review of published research generally points to market expectations of continued growth in online enrollment with some caveats. There is an increase in the acceptance of online education products by both students and employers. While more colleges are chasing adult prospects, the National Adult Learner Coalition sees adult workers using online education products as an untapped resource to fill the skills gap increasingly seen by US employers, declaring, "America's employers need workers with higher level skills, whether obtained through pursuit of a degree, or through shorter term training represented by very different credentials like certifications, certificates, and newer forms of postsecondary credentials such as badges and micro-degrees.[xvii]" This outlook is consistent with NAU's efforts to align our strategic plan with workforce needs and expand our portfolio of stackable credentials and certificates.

NAU's future enrollment plans therefore represent a more well-rounded approach toward student recruitment, retention, academic program offerings, and delivery options. An overall outlook based on current ABOR 2025 metrics and our current strategies is as follows: our enrollment goal is 34,909 by 2025, and our current enrollment is 30,581, with 26,693 undergraduate students and 3,942 graduate students. As a result, we have less than 4,000 students we expect to increase our enrollment by in the next 6 years, an average of just over 650 additional students each year. These students are projected to come through a modest increase in freshman enrollment. Increases are also planned in transfer students to all delivery models, efforts to improve retention, targeted graduate enrollment growth and significant online enrollment growth.

Our retention goal is 80%, which we recognize is aggressive, particularly with an increasing population of at-risk students. NAU's student diversity has grown from 30.3% diverse students in 2012 to 37.1% in Fall 2018 (IPEDS methodology for Diverse students includes all categories with the exception of White, International, and Non-Specified). After a single year drop in retention to 73.5%, we are currently projecting at 78% freshman retention rate for Fall 2019. If we met 80% freshman retention with our current freshman cohort, rather than waiting until 2025 to meet this goal, this would increase our enrollment by 328 students annually and more than 1,000 in 4 years. Our 6-year graduation rate goal is 57.5% and it is currently 52.4%. Increasing freshman retention is key to meeting this goal, which is based on the same first-time, full-time freshman cohort. While not enrollment growth in the traditional sense of bringing more students to the university, increased retention and persistence does represent a significant growth area for our overall enrollment. This growth results from our focus on student success—more access through transfer students, more degree completion of those with some college, more retention and higher graduation rates of those who start college with us, and more potential students staying at NAU to take advantage of our growing graduate degree offerings. Significant resources and effort have been put into retention and persistence strategies, including investment in the university-wide implementation of the Salesforce CRM system, which is planned for further expansion in its capacity. Additionally, professional development for staff and faculty to fully utilize Learning Management System (LMS) capabilities are underway. Restructuring of the Enrollment Management and Student Affairs Division into two separate leadership positions at a Vice Presidential level has increased the focus on each of these critical areas while

maintaining collaboration among the responsible units.

We set goals for each area of the enrollment subgroups in our strategic enrollment management plan through to 2025 to meet the metrics. Within these overall goals of undergraduate, graduate, and high demand fields there are Flagstaff Campus, statewide, PBC, online, and international student internal metrics. The reason these subgroup metrics are internal is because they are highly dynamic and dependent on a number of external factors, requiring constant adjustment. Making these subcategories public to a wide audience would impose unneeded scrutiny on successes and failures in one or more categories and criticism of planning efforts. For example, even a small increase of international students is often of greater financial benefit than larger traditional undergraduate numbers due to net tuition received. As a result, while we have subgroup goals that go out to 2025 we evaluate and adjust annually and utilize this planning in our tuition setting process that is presented to the Board. We have been conservative in past years and as a result have had excess tuition collection each year. Last year we were more aggressive in our planning, and although we still had enrollment growth, it was overshadowed by the fact that it was not as large as anticipated. Declines in online and community campus enrollment significantly impacted revenue. As an overall mix of student enrollment, however, NAU's online student population grew as a percentage of the whole until 2016 when the enrollment grew but the percent flattened while NAU's statewide population has declined both in enrollment and percent of the mix since 2008. A review of enrollment trends provides background on the need to diversify the mix of students to be less reliant on the Flagstaff Campus for future growth in the overall percentage mix (see chart below):

	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Total Enrollment	21,352	22,507	23,600	25,204	25,364	26,002	26,606	27,715	29,031	30,368	31,057	31,073
Flagstaff	13,989 (66%)	14,766 (66%)	16,032 (68%)	17,529 (70%)	17,761 (70%)	18,341 (71%)	19,320 (73%)	20,134 (73%)	21,107 (73%)	22,134 (73%)	22,740 (73%)	23,140 (74%)
Online	2,228 (10%)	2,593 (12%)	2,662 (11%)	2,956 (12%)	3,293 (13%)	3,759 (14%)	3,822 (14%)	4,439 (16%)	5,166 (18%)	5,644 (19%)	5,846 (19%)	5,640 (18%)
Community Campuses	4,492 (24%)	4,517 (23%)	4,230 (21%)	4,033 (19%)	3,670 (17%)	3,311 (15%)	2,923 (13%)	2,613 (11%)	2,238 (10%)	2,059 (9%)	1,960 (8%)	1,793 (7%)

The combination of enrollment trends moving away from traditional undergraduates toward online enrollment, coupled with the need for increased numbers of college graduates, requires the university to look to increased online enrollment as its main growth driver. It is critical that we become increasingly aggressive in this enrollment area. The recent decline to the entering freshman cohort on the Flagstaff Campus is recognized as representative of the overall high school graduation population nationally and regionally, the flattening of the traditional college-going population immediately from high school, and the competitiveness of the higher education market. While community campus enrollments are no longer declining and slight increases are occurring, with some sites excelling and others posing more of a challenge, as a whole, the increases will be modest.

It is anticipated that short-term enrollment growth will occur through the identification and promotion of existing online programs that show the best short-term growth potential, with longer-term growth coming from the development of new online offerings in high demand

programs. Additional growth will be developed through partnerships with targeted organizations, such as feeder high schools, key community colleges, businesses, and government entities. This includes increasing institutional and program awareness and visibility in key student population markets, further evaluating our competitive strengths and weaknesses in the academic program market and adjusting programming, expanding strategic partnerships, and further defining intentional student journeys through the entire student process from recruitment to graduation.

In addition to the program growth areas in online and hybrid learning modalities, we have engaged broad cross-sections of our campus community, including academic leaders, faculty, and student support staff, to develop and launch new programs in targeted areas aligned to workforce needs and diversified enrollment mix. Just a few examples include the Bachelor of Science in Indian Country Criminal Justice, the new Master of Public Administration in Schenzhen which will be a gateway to the growing MPA market in China, redesign of our psychology online programs, and new degrees and certificates in cybersecurity.

A move from the 2024-2025 ABOR metric path to the increased emphasis on online enrollment strategies as defined in this Phase I report are shown in the table below. Flagstaff Campus undergraduates currently account for 68.7% of all NAU enrolled students. Under the proposed strategies NAU will move to an enrollment mix of residential campus and online students more in line with our sister institutions, which will result in an anticipated residential campus undergraduate population of approximately 57.5% of our total student population by 2024-2025.

	2014-15	2015-16	2016-17	2017-18	2018-19	2019-20	2020-21	2021-22	2022-23	2023-24	2024-25
FLGMT UG On-Campus % of Total	66.9%	66.6%	67.1%	70.4%	68.7%	69.3%	67%	65.2%	63.1%	60.7%	57.5%
FLGMT UG On-Campus	18,330	19,144	20,128	21,619	21,007	21,486	21,547	21,547	21,547	21,547	21,547
Total	27,396	28,738	29,989	30,704	30,581	30.987	32,165	33,029	24,136	35,526	37,478

We have spent significant time and resources putting the necessary systems in place to facilitate student communication and data collection to make adjustments in strategies and tactics more quickly. Improvements have occurred in the reports that are available from the management system to monitor enrollment goals, assist in planning, and make the necessary adjustments. Risks for managing a comprehensive enrollment strategy at NAU include continued reliance on multiple technology tools for data sources based on comfort with old systems. While the university has migrated to Salesforce as our CRM system, some departments are still utilizing legacy systems and have not fully integrated to Salesforce, making accurate student information for all campuses and learning modalities a challenge as we work through the ongoing implementation phase with staff professional development. An institutional dashboard is under development to help bring all the information together into one report so that staff can understand the importance of the CRM migration and the resulting strategic use of data to affect student outcomes and university enrollment goals.

We are aggressively pursuing graduate education to complement our overall campus and academic profile and connect to the investments we have made. We have brought proposals to

the Board for new academic programs, growth in accelerated 3+2 and 4+1 programs, strategic budget priorities, and campus initiatives that have been launched.

The chart below provides a historical overview on the percent of enrollment mix of NAU's student population between undergraduate and graduate enrollments. Aligning with ABOR 2025 performance metrics around graduate student enrollment and degree completion, as well as through careful consideration of program expansion as envisioned in NAU's academic strategic plan and recent degrees brought to the Board, will return NAU to a more appropriate enrollment mix between undergraduate and graduate student enrollment.

Undergraduate vs. Graduate Enrollment Trend

	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Total Enrollment	21,352	22,507	23,600	25,204	25,364	26,002	26,606	27,715	29,031	30,368	31,057	31,073
Percent Undergraduate	73%	75%	78%	80%	82%	84%	85%	86%	87%	87%	87%	87%
Percent Graduate	27%	25%	22%	20%	18%	16%	15%	14%	13%	13%	13%	13%

Moving from a decentralized enrollment management system to the centralized system adopted under the One NAU model has required significant collaboration among NAU's leadership team and a transition of numerous systems and practices. This modeling assisted all leaders and teams involved in the recruitment, admissions, and enrollment process in understanding the interconnectivity of the unit goals to the overall institutional goals. To this end, leading enrollment management efforts in a comprehensive and inclusive manner in the future at NAU was determined to be a much more extensive position and Executive Team responsibilities were reorganized to allow additional focus for this priority area. A separate position was developed for Vice President of Student Affairs and responsibilities for student organizations, campus health, student activities, the Dean of Students and other student engagement and success operations were put under this new position. Additionally, other campus administrative functions were reassigned.

In addition to the changes to our tuition structure for the student populations anticipated to grow in the overall enrollment mix in the future, including online and graduate students, NAU reviewed its financial aid strategies and yield as part of this comprehensive project. Below is information from the last financial aid report (2018 with data from 2017), which demonstrates NAU's overall financial aid resources as more reliant on institutional aid that our sister institutions. In a competitive higher education market, students are evaluating the final cost of attendance to them individually more than they are the advertised tuition price when they are making their final university admission decision. NAU's total need-based aid package remains competitive within the Arizona university system and the average debt with which our undergraduate students graduate has actually declined each year from 2015 through 2018 and is more than $1,000 lower than the 2013 level. Given that NAU's Pell-eligible student population remains high, at 32%, it is important that we maintain a priority for need-based aid awards.

2018 ABOR Financial Aid Report

not including Self Help (Loans, Federal Work Study, GA)

	NAU					ASU					UA				
Scholarships And Grants $	Students showing Need	Students not Showing Need	Undergrad Total	Grad/First Professional	Total	Students showing Need	Students not Showing Need	Undergrad Total	Grad/First Professional	Total	Students showing Need	Students not Showing Need	Undergrad Total	Grad/First Professional	Total
Federal	47,157,208	230,043	47,387,251	500,007	47,887,258	173,988,199	14,531,233	188,519,432	9,671,847	198,191,279	57,229,057	4,587,260	61,816,317	3,878,245	65,694,562
Pell	43,192,215	-	43,192,215	-	43,192,215	140,218,711	1,107,452	141,326,163	-	141,326,163	48,562,041	523,077	49,085,118	-	49,085,118
Other	3,964,993	230,043	4,195,036	500,007	4,695,043	33,769,488	13,423,781	47,193,269	9,671,847	56,865,116	8,667,016	4,064,183	12,731,199	3,878,245	16,609,444
State	-	-	-	-	-	620,691	28,443	649,134	13,700	662,834	144,513	-	144,513	-	144,513
Arizona	-	-	-		-	498,370	-	498,370	-	498,370	131,313	-	131,313	-	131,313
Outside Arizona	-	-	-		-	122,321	28,443	150,764	13,700	164,464	13,200	-	13,200	-	13,200
Institutional	**86,226,405**	**32,154,982**	**118,381,387**	**13,934,406**	**132,315,793**	**263,616,828**	**116,775,352**	**380,392,180**	**47,847,698**	**428,239,878**	**92,838,267**	**73,601,735**	**166,440,002**	**40,270,023**	**206,710,025**
AFAT	3,709,235	-	3,709,235	-	3,709,235	14,538,238	1,000	14,539,238	-	14,539,238	8,319,583	-	8,319,583	-	8,319,583
Private / External	**8,467,802**	**2,014,289**	**10,482,091**	**1,325,707**	**11,807,798**	**31,772,270**	**66,902,390**	**98,674,660**	**19,886,445**	**118,561,105**	**19,643,257**	**28,827,145**	**48,470,402**	**25,725,524**	**74,195,926**
Total Scholarships and Grants	145,560,650	34,399,314	179,959,964	15,760,120	195,720,084	484,536,226	198,238,418	682,774,644	77,419,690	760,194,334	178,174,677	107,016,140	285,190,817	69,873,792	355,064,609

	NAU					ASU					UA				
Scholarships And Grants Average	Students showing Need	Students not Showing Need	Undergrad Total	Grad/First Professional	Total	Students showing Need	Students not Showing Need	Undergrad Total	Grad/First Professional	Total	Students showing Need	Students not Showing Need	Undergrad Total	Grad/First Professional	Total
Federal	4,409	3,334	4,402	2,907	4,379	4,823	6,213	4,907	9,779	5,029	4,702	5,533	4,755	12,842	4,939
Pell	4,146		4,146		4,146	4,028	1,405	3,970		3,970	4,547	1,387	4,439		4,439
Other	2,218	3,334	2,259	2,907	2,314	3,901	8,475	4,609	9,779	5,064	5,813	8,992	6,552	12,842	7,398
State						1,789	7,111	1,849	4,567	1,872	1,235		1,235		1,235
Arizona						1,562		1,562		1,562	1,162		1,162		1,162
Outside Arizona						4,369	7,111	4,711	4,567	4,699	3,300		3,300		3,300
Institutional	**7,501**	**6,817**	**7,302**	**6,992**	**7,268**	**6,691**	**7,624**	**6,952**	**8,199**	**7,073**	**6,750**	**8,688**	**7,489**	**7,370**	**7,465**
AFAT	2,455		2,455		2,455	2,440	1,000	2,439		2,439	4,716		4,716		4,716
Private / External	**3,663**	**2,759**	**3,446**	**4,017**	**3,502**	**3,767**	**13,535**	**7,376**	**6,755**	**7,264**	**4,516**	**8,234**	**6,174**	**7,604**	**6,605**
Total Scholarships and Grants	9,661	6,749	8,925	6,897	8,718	9,264	10,051	9,480	9,196	9,450	10,854	10,137	10,574	9,915	10,437

Throughout the strategic enrollment management planning effort, NAU's team maintained a commitment to diversifying the overall student enrollment among all segments. For this reason, given the current lack of competitiveness of NAU in providing awards to students not showing need (generally merit-only awards), NAU does not recommend making any changes at this time in this award structure, particularly for resident students. The university has adopted a financial aid yield model, however, to assist with monitoring the continued enrollment/persistence of students who receive financial aid. This yield modeling will inform future financial aid award decisions, particularly related to resident undergraduate students. Additionally, as has been outlined, this report does recommend diversifying enrollment which has the effect of including greater numbers of students who receive less institutional aid, including non-resident students, online students, and graduate students, thus helping in the overall net tuition collections.

Finally, NAU is monitoring whether the Lumberjack Scholarship can continue as a guaranteed full tuition scholarship or whether the amount will need to be capped at a flat scholarship amount with the option to stack additional scholarships where appropriate. The Lumberjack Scholarship has been a successful tool in recruiting high achieving Arizona resident students to NAU, with its minimum criteria of a 3.5 core GPA, no deficiencies in the university admissions criteria, and no high school grades of "C" or lower. This scholarship provides early outreach and includes a long-term commitment to students so any changes would need to be thoughtful and prospective with advance notice of implementation.

Phase I of this report has included collection of extensive historical information and modeling of trend data in order to develop NAU's projections by student enrollment segment for the future. Financial modeling has been included to ensure a sustainable future for NAU through this diversified enrollment portfolio. Finally, academic leadership and departmental leadership and organization has been selected to champion a vision for developing new academic programs, particularly in online delivery models and graduate programs that meet workforce and student demands in Arizona and draw a national market. All of this work will allow NAU to continue its competitive edge in the marketplace.

References and Attachments

[i] https://info.credly.com/

[ii] https://www.naceweb.org/career-readiness/competencies/career-readiness-defined/

[iii] https://www.careerleadershipcollective.com/career-innovation-showcase

[iv] https://caes.ucdavis.edu/news/articles/2014/01/groundbreaking-digital-badge-system-for-sustainable-agriculture-program-2

[v] https://onlinelibrary.wiley.com/doi/full/10.1111/bjet.12200

[vi] https://pdfs.semanticscholar.org/44e4/e6342d39cdb38058052c0ca577586e2fb598.pdf

[vii] https://madisoncollege.edu/continuing-education

[viii] https://www.luminafoundation.org/resources/connecting-credentials

[ix] https://www.kornferry.com/

[x] https://business.linkedin.com/talent-solutions/blog/trends-and-research/2018/industries-biggest-talent-shortages-2030

[xi] Erin Sparks and Mary Jo Waits, "Degrees for What Jobs? Raising Expectations for Universities and Colleges in a Global Economy" (2011)

[xii] https://www.simplilearn.com/

[xiii] https://www.pluralsight.com/

[xiv] https://www.mindedge.com/

[xv] https://www.ucertify.com/

Attachments

#1 Hannover-BLS Analysis

#2 Computational Thinking

[xvi] Nathan Grawe, *Demographics and the Demand for Higher Education*

[xvii] National Adult Learner Coalition, *Strengthening America's Economy by Expanding Educational Opportunities for Working Adults*

Attachments

#1 SEM Committee Membership List

#2 ABOR 2012 Pledge Analysis

#3 ABOR 2012 Pledge Analysis PPT

#4 Spring 2018 Pledge Analysis

#5 Sensitivity Analysis of Enrollment Mix 1

#6 Sensitivity Analysis of Enrollment Mix 2

Attachment #1: Hannover-BLS Analysis

Areas of expansion include a review of the projected state occupational labor market needs based on high growth fields in the Arizona labor market requiring a masters degree for workforce entry (Source: Bureau of Labor Statistics)

Field of Study	Jobs Opening Volume		Change
	2016	2026	
Finance	92610	111280	20.2%
Management Science	70.350	83450	18.6%
Computer Science	56270	69360	23.3%
Information Technology	51130	64130	25.4%
Computer Engineering	32790	41620	26.9%
Computer Software Engineering	28790	36960	28.4%
Social Work	19700	26230	33.1%

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Changing a Generation's Way of Thinking: Teaching Computational Thinking Through Programming

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Computational thinking (CT) uses concepts that are essential to computing and information science to solve problems, design and evaluate complex systems, and understand human reasoning and behavior. This way of thinking has important implications in computer sciences as well as in almost every other field. Therefore, we contend that CT should be taught in elementary schools and included in every university's educational curriculum. Several studies that measure the impact of teaching programming, analytical thinking, and CT have been conducted. In this review, we analyze and discuss findings from these studies and highlight the importance of learning programming with a focus on the development of CT skills at a young age. We also describe the tools that are available to improve the teaching of CT and provide a state-of-the-art overview of how programming is being taught at schools and universities in Colombia and around the world.

Keywords: computational thinking, programming, computer science education, schools, higher education

Computational thinking (CT) is a way of approaching everyday situations and solving problems by utilizing concepts that are fundamental to computer science. As Wing (2006, p. 1) stated, "Computational thinking is reformulating a seemingly difficult problem into one we know how to solve, perhaps by reduction, embedding, transformation, or simulation." This process not only prepares students in the field of computer science but also provides students with tools and skills to approach and solve a wide range of problems in different areas of knowledge (Werner, Denner, Campe, & Kawamoto, 2012). Nowadays, CT influences fields related to the natural and social sciences and facilitates the acquisition of skills to solve problems, design systems, and understand the power and limits of human and machine intelligence.

In this review, we begin with a section that describes our literature search strategy. Next, we include a section in which we discuss how programming can be used to develop skills related to CT in students from school to higher education, and we highlight the importance of peer-based collaborative environments and concept maps and how these tools enhance a meaningful programming experience. In the third section, we review the impact of programming in diverse fields of study as well as the issues faced when teaching and learning programming in higher education. Last, we provide a state-of-the-art overview of how programming is being taught in schools. In this final section, we address the challenges faced by early programmers and describe the tools that are available to improve the teaching process of CT at schools worldwide.

Method

To obtain an overview of the state of the art of teaching and learning programming in educational institutions, we made an extensive, worldwide search of papers in journals and proceedings of the Association for Computing Machinery Digital Library, as well as in journals specialized in education of computing or programming (e.g., *Review of Educational Research*, *Computer Science Education*, *Education and Information Technologies*, *Computers in Mathematics and Science Teaching*, *Journal of Virtual Worlds Research*, *Educational Technology & Society*, among others). Several key words and key phrases were used throughout our search. Among these were "teaching/learning programming," "issues in teaching/learning programming," "challenges for novice programmers," "programming in schools," "programming in higher education," "coding for children," "woman in computing," "coding in the 21st century," "programming in the United States/Europe/Asia/Latin America," "approaches to teaching/learning programming," "collaborative teaching/learning in programming."

Subsequently, we searched for literature that might not be published in indexed journals or proceedings. We performed an open search in Google Scholar using the same key words and key phrases to gather information from associations of teachers and individual initiatives in the field. Given that these references were from unindexed sources, we decided to restrict the search to associations of teachers in leading countries in this area. Additionally, we gathered information from nonprofit organizations that aim to encourage the teaching and learning of programming at any age.

We ended up with 92 references, including journal articles, reviews, proceedings, short communications, and governmental standards from established associations of teachers in the United States, the United Kingdom, France, and Germany. No restrictions regarding the date of publication were taken into account. However, information published in the last 15 years was the most relevant for this review. A deep and careful examination was conducted with each of the references found. The most relevant information related to the processes, practices, tools, and experiences in teaching and learning programming both from K–12 and in higher education, was retrieved.

Results

Programming as a Tool for Mind Development

Several lines of evidence exist to support the implementation of CT in schools as well as in higher education. First, children are now, more than ever, exposed to considerable amounts of data, sometimes not curated, delivered in several formats, and most of the time, not interconnected. CT can provide children with the tools to extract the knowledge that might be hidden in the data. Second, we are used to teaching reductionist science (i.e., isolated mechanisms or metabolic pathways), but need to start teaching the systems as they are: complex. Most of the times, because of the lack of time, teachers do not ask or guide their students to make connections between the materials they receive. Third, CT helps enhance the thinking abilities as individuals can superimpose and combine multiple layers of abstraction as a computer programmer does when developing algorithms.

To understand the complexity and importance of teaching CT, it is important to differentiate among specific key terms: computer programming, computational thinking, and algorithmic thinking. We define computer programming as the process through which a person is able to provide a set of instructions that will communicate, as specifically and accurately as possible, a procedure, method, practice, or task to a machine. This set of instructions must be coded using a specific programming language (Vihavainen, Airaksinen, & Watson, 2014). We define CT as a way of *reasoning* that compiles several high-level skills and practices that are at the heart of computing, but applicable to many areas far beyond computer science. The distinction between CT and algorithmic thinking in the literature is somewhat unclear. However, in this review, we define algorithmic thinking as a way of obtaining a solution through a series of steps. Thus, CT, as defined by Syslo (2015), is a broader term that involves among other skills, algorithmic thinking, logic, abstraction, generalization, decomposition, and debugging.

In theory, teaching programming is the best approach to teach CT. Programming is initially taught by introducing the student to a programming language. Yet very soon after the course begins, the student is faced with several challenges including problem-solving situations, debugging, program design, and implementation. For a long time, teaching to program was considered the best tool for developing minds. However, by the mid-1980s, results of several studies suggested that teaching to program failed to catalyze the development of higher-order thinking skills (Sleeman, 1986). The reasons for this failure are complex. Whereas some authors argue that the way programming was taught was to blame, others blame the nature of programming itself (Sleeman, 1986).

Several studies have shown that students who take programming classes perform better on logical reasoning and problem-solving skills (Tu & Johnson, 1990). To be successful in developing a critical mindset, a computer programming course must (a) specifically define the learning and teaching objectives (including problem solving as an objective), (b) include appropriate educational tools and strategies such as the design and use of concept maps, and (c) consider and understand the differences between novices and experts in programming (specifically differences in their levels of abstraction). Nowadays, technology is ubiquitously

present in students' life and the fear of interacting with the physical machines has diminished. Werner, Denner, et al. (2012) showed that middle school students who had more access to computers and/or more confidence with them, performed better in their problem-solving exercises and algorithmic thinking. However, as noted by Saeli, Perrenet, Jochems, and Zwaneveld (2011) and supported by studies performed by both Kurland, Pea, Clement, and Mawby (1986) and Papert (1993), teaching programming can be a very difficult task. Therefore, suitable educational tools and strategies must support programming courses, so that any individual may become proficient in programming and may further develop their thinking abilities in a reasonable time.

Programming must be seen as a tool to develop concepts and skills related to CT and computer science (e.g., resourcefulness, problem solving, abstraction, algorithmic thinking), rather than a human–machine communication tool, related to the information and communications technology field (ICT; French Academy of Sciences, 2013). Thus, instead of teaching students solely how to write code, programming courses must include the development of skills related to CT as a learning objective. Students who are exposed to CT through programming, develop algorithmic thinking, problem solving, logic, and debugging skills. Hence, the programming that is taught in computer science should be focused on the development of CT skills. Furthermore, computer science must be considered an essential discipline (on a par with mathematics, for example) that every person should learn from primary school onwards. According to Jones, Mitchell, and Humphreys (2013), computer science comprises foundational principles as well as widely applicable ideas and concepts. This discipline incorporates techniques and methods for solving problems and advancing knowledge (such as abstraction and logical reasoning), and a distinct way of thinking and working that sets it apart from other disciplines.

Concepts within computer science have longevity (most of the ideas and concepts from 20 or more years ago are still applicable today) and every core principle can be taught or illustrated without relying on the use of a specific technology. Therefore, teaching fundamentals and concepts in programming as the core for an entire discipline, instead of solely training students in the details of specific programming languages—which might become useless with time—is crucial for the development of CT skills (French Academy of Sciences, 2013).

Peer-Based Collaborative Environments and Concept Maps

Peer-based collaborative environments have shown to significantly stimulate and enrich educational programming (Jakovljevic, 2003). In these collaborative environments, students are able to use web-based conferencing, desktop videoconferencing, and instant messaging to develop their tasks in a collaborative virtual team. Despite the availability of online tools and tutorials, hands-on instruction and guidance from peers or instructors is crucial for students to be able to rapidly solve their inquiries so that they can increase the quality of their projects and solidify what they have learned. Furthermore, there is evidence that peer-based collaborative environments help engender enthusiasm for programming among students and help students complete projects with grander goals in less time (Chase & Okie, 2000).

In parallel with collaborative environments, concept maps have also been shown to enhance a meaningful programming experience for learners at a higher education institution (Jakovljevic, 2003). Concept maps are graphical representations of the knowledge that helps the learner organize the information, analyze it, and then relate and connect it to create new structures that can be applied to any subject (Novak, 1991). This educational tool is considered a metacognitive tool, that is, a strategy that helps learning or understanding knowledge (Novak, 1990). In the field of education, concept mapping was developed in 1972, but it was only in the late 1980s and early 1990s that it was identified as a tool for building powerful knowledge structures by engaging the students in a meaningful learning experience (Cardellini, 2004; Novak, 1998).

Concept maps can guide a student from lower to higher levels of thinking as depicted in the Bloom's taxonomy. Furthermore, they can help represent all domains of learning, the cognitive, the affective, and the psychomotor (Novak, 1990). Previous studies have shown how the implementation of concept maps has enhanced learning in mathematics (Cardemone, 1975; Novak & Afamasaga-Fuata'i, 2009), genetics (Bogden, 1997), engineering (Turns, Atman, & Admas, 2000), chemistry (Pendley, Bretz, & Novak, 1994), physics (Moreira, 1977), and programming (Jakovljevic, 2003). Novice programmers can use concept maps to design their programs, to help them think about what the program will do, and to describe how they will execute a task. Also, concept maps can help novice programmers organize basic concepts of programming to then use them correctly in their programs (Novak, 1991). The importance of pedagogical tools in programming courses used to achieve the goals of CT will be more thoroughly developed in the fourth section.

Teaching and Learning Programming in Higher Education

Over the last decade, computer science and programming have grown remarkably and have permeated several fields, such as biology, chemistry, physics, medicine, engineering, art, music, and social sciences. Furthermore, new subfields such as bioinformatics, internet security and ethics, gaming, artificial intelligence, among others have been created (Kay, van der Hoek, & Richardson, 2005). As shown in Table 1, computer programming focused on the development of CT skills is an ability that is very useful and can be very rewarding for students in numerous disciplines (Piteira & Costa, 2012). However, teaching programming languages in higher education has proven to be an extremely difficult and challenging task for professors and a difficult subject for students to learn (Mow, 2006). Therefore, experts in this area have been analyzing the difficulties faced by novice students taking introductory programming courses, especially as studies indicate that programming places a heavy cognitive load on freshmen students (Ahmadzadeh, Elliman, & Higgins, 2005; Flowers, Carver, & Jackson, 2004). It is important to underscore the fact that most freshmen students have had no programming background knowledge or experience (Tuugalei & Mow, 2012). According to Flowers et al. (2004), even after 2 years of learning programming, many students are still struggling to be proficient.

Programming requires memorizing a wide range of information and displaying several skills at the same time. A student must think about the details of syntax

TABLE 1

Fields in which programming and computational thinking (CT) can be directly applied

Area	Activities related to programming and CT
Biology	Genome sequencing, genome assembly, and gene prediction
	Protein interaction modeling
	Metabolic pathway reconstruction
	Population and systems biology
Chemistry	Discovery and design of drugs
	Molecular dynamics simulations
	Chemical pathways modeling
	Study of fundamental properties of atoms and molecules
Physics	Physical behavior of materials
	Optical performance simulations
	Astrophysics modeling
	Physical interaction in biomolecules
Medicine	High-throughput biomedical assays
	Neuronal pathways modeling
	Physiology performance simulations
	Medical surgery automation
	Analysis of drugs and environmental toxins
	Medical illustration
Engineering	Mobile and internet computing
	Gaming
	Robotics
	Computer and network security
	Artificial intelligence
	Data base systems
Arts	Image design
	Movie animation
Music	Acoustics simulations
	Recording techniques
	Sound synthesis and manipulation
	Computer music
Social Sciences	Demographic simulations
	Pandemic reaction modeling
	Computational finance

and semantics of the programming language used, elaborate some mental model of how to solve each problem, and be able to distinguish between solving the problem and specifying the solution in a way that a computer would be able to execute it (Pane & Myers, 1996). Consequently, a student must be capable of using abilities related to CT such as algorithmic thinking (in order to obtain a solution through clearly defined steps), evaluation (ensuring that an algorithmic

solution is a good one), decomposition (splitting the situation in several parts), and abstraction (in order to basically make problems or systems easier to think about by removing unnecessary complexity and details; Curzon, Dorling, Ng, Selby, & Woollard, 2014).

Numerous problems associated with the learning of programming have been described for several years. Lahtinen, Mutka, and Jarvinen (2005) stated that novice programmers are typically limited to the surface knowledge of programs, often using a "line by line" programming approach instead of meaningful program structures involving CT skills. This approach most likely leads to a failure in terms of applying the knowledge they have obtained. Additionally, it seems that students may know the syntax and semantics of individual statements, but do not know how to combine them into valid programs, as they lack detailed mental models, and are thus unable to solve problems in an efficient way (Winslow, 1996). Moreover, most students present several issues when they have to understand notions about loops, conditionals, arrays, and recursion (Robins, Rountree, & Rountree, 2003) as well as pointers and references, finding bugs from their own programs, structured and abstract data types, and error handling (Lahtinen et al., 2005; Piteira & Costa, 2013; Tuugalei & Mow, 2012).

In addressing these problems, diverse strategies have been tested in freshmen students. After an extensive survey of both students and professors, Lahtinen et al. (2005) reported that practical sessions in computer rooms were rated as the most useful strategies. On the Internet, students encounter a significant number of examples of codes (executable), programming tutorials, educational videos, and contents available on educational platforms such as Moodle and Blackboard (Piteira & Costa, 2013).

Vihavainen et al. (2014) conducted a literature review to learn about the different intervention approaches to address the concerns. The authors grouped interventions into four different categories. The first category was Collaboration and Peer Support. This category included (a) Peer-Led Team Learning activities in which team-based learning is provided to help the students in introductory programming courses (Lasserre & Szostak, 2011); (b) Pair Programming Activities in which two students with specific roles work collaboratively at one computer on the same design, algorithm, code, or test (Williams, McDowell, Nagappan, Fernald, & Werner, 2003); and (c) Cooperative and Collaborative Practices in which an undergraduate student co-teaches the class as the students are organized in cooperative groups (Chase & Okie, 2000). The second category was named Relatable Content and Contextualization. This one included (a) Media Computation in which design, audio, and web page programs are used to facilitate teaching programming (Tew, Fowler, & Guzdial, 2005); (b) Real-World Projects in which a set of lab exercises based on real-world problems are used by the teacher with the class (De La Mora & Reilly, 2012); and (c) Courses involving games in which using game maker platforms students are encouraged to design a game as desired (Rankin, Gooch, & Gooch, 2008).

The third category was named Course Setup, Assessment, and Resourcing. This group of interventions included (a) Adjusting Course Content so that which students' bottlenecks are analyzed and then the requirements are adjusted (Shaffer & Rosson, 2013) and (b) Changing the Grading Schema so that all assignments

are evaluated in a way that would increase the pass rate and consequently generate a better atmosphere in the class (Nikula, Gotel, & Kasurinen, 2011). Finally, Category 4 was named Hybrid Approaches. This category combines the methodologies applied in the previous three categories, including Media Computation with Pair Programming, Peer-Led Team Learning, and Collaborative Learning with Relatable Content.

At the end of their review, Vihavainen et al. (2014) concluded that, on average, using these types of interventions improves programming courses pass rates by nearly one third compared with a traditional lecture and lab-based approach. These authors also concluded that courses with relatable content (e.g., media computation) and cooperative elements (e.g., pair programming) had increased pass rates and intrinsic student motivation, whereas courses that relied exclusively on a single approach resulted in students performing poorly.

We want to highlight a specific example at the Universidad de los Andes (Bogotá, Colombia). For at least a decade, the Systems and Computing Engineering Department has been conducting surveys and working on some of the most common problems related to teaching and learning programming. These include (a) motivational problems (i.e., finding that some students have the impression that success depends on something beyond their control regardless of the understanding of the theory, algorithmic skills, or the time spent working on a program), (b) lack of congruence between the concepts and skills taught in introductory courses and the ability to write specific programs to solve a problem in an efficient way, and (c) methodological problems in teaching programming. The instructor expected that students would be able to learn on their own by going over examples presented in class and are then expected to design their own programs (Villalobos, Calderon, & Jimenez, 2009; Villalobos, Casallas, & Marcos, 2005).

In order to address the issues with computing courses described above, the Systems and Computing Engineering Department at Universidad de los Andes has been working on a robust interactive platform called Cupi2 (http://Cupi2.uniandes.edu.co) since 2006. This interactive platform encompasses an extensive set of resources that include lectures, workshops, books, articles, lab examples, concept maps, tutorials for students and teachers, as well as reports about class schema and student performance on every programming course taught at the university (Vega, Jimenez, & Villalobos, 2013). Cupi2 was developed as an initiative to tackle major challenges in teaching and learning programming. The main goal was to design learning strategies that use problem-based learning (PBL) and bottom-up approaches to introduce simple concepts (data types, operators, and expressions) and then lead students toward more complex concepts such as control structures, methods, parameters, vectors, and collections in a Java environment (Villalobos & Casallas, 2006).

An introductory course to programming called APO I (algorithms and object-oriented programming) is taught every semester at Universidad de los Andes. This course uses the Cupi2 interactive platform and is taken by students in any of the undergraduate programs from the School of Engineering, the School of Sciences (except for students in biology and microbiology), and some students in the music department, reaching more than 1,000 students per semester. Each class has fewer than 26 students (to improve the one to one interaction between students and

teachers) and is divided into six levels, which reflect the difficulty and skills required. In Levels 1 to 5, students are taught the main concepts related to object-oriented programming through lectures and examples included in the textbook written by professors associated to the Cupi2 interactive platform. Furthermore, students attend lab sessions where they have the opportunity to practice problems that are partially solved in a java environment called Eclipse (http://www.eclipse.org/), using the resources available in the Cupi2 platform. Through *CupiTaller*, which stands for "CupiWorkshop," students from all academic programs taking APO I or APO II (the course that follows APO I) may access a physical space where they may receive personalized tutoring to strengthen their programming abilities.

At the end of the course (Level 6), students are challenged to solve a complete exercise using all the tools, syntax, and skills learned throughout the semester. These efforts have resulted in an improvement in the success rates and motivation of the students. A nearly 50% decline in the number of students failing the course has been observed as well as a consistent reduction in the number of students that drop the course. Moreover, questions related to the students' perception of the course showed a 20% increase after the introduction of Cupi2 (Villalobos et al., 2005). Around 25 universities in Colombia work with and develop materials for Cupi2 each year, creating a large and diverse community for teaching and learning programming (Villalobos et al., 2009).

Unfortunately, regardless of all the efforts done to overcome the difficulties associated to learning programming (i.e., Cupi2), a substantial number of students are still challenged by abstract programming concepts and logical reasoning. Responses to the end of semester surveys of the APO I course indicate that students in Level 1, particularly, believe that they could have learned more if they would have had prior experience with programming before taking this first-semester course. In short, the lack of prior experience limits the skills and syntaxes that can be taught, thus hindering the learning of specialized languages such as C, C++, Matlab, Python, Arena, Strata, ArcGIS, and other useful programming languages. To address this concern, we contend that high school students should learn skills related to CT and algorithmic logic, so that it will be easier for them to learn and adapt to new programming languages as well as different software during their undergraduate studies. High school students should be exposed to the development of logic, abstraction, decomposition, and evaluation as well as the comprehension of basic algorithmic design, in order to facilitate the learning of programming in higher education.

An unpublished study at Universidad de los Andes provides support for this claim. Briefly, we retrieved data from all students who took APO I between the spring semester of 2010 and the spring semester of 2015 and identified the high school that the students had attended. As the total number of high schools was more than 900, we selected 61 schools that represented more than half of the students. Each school was contacted directly to assess if programming was taught at any level. Analyses were conducted on a total of 3,855 students using R (R Development Core Team, 2008). Results indicated a significant difference in the average final grades between students who had been previously exposed to programming in high school and those who had had no prior exposure to programming (p value = 2.53

e^{-08}). Students who had been exposed to programming in high school obtained an average grade of 4.5 out of 5.0 ($SD = 0.76$), and students with no prior experience in programming obtained an average grade of 3.9 ($SD = 0.79$; $d_{corrected} = 0.77$).

Introducing students in elementary and higher school to algorithmic thinking, abstraction, evaluation, problem solving, decomposition, and debugging will most certainly help develop critical skills before college. These skills may result in an easier transition from school to university, and allow professors to focus their undergraduate programming courses on teaching useful features of specific programming languages, as well as reinforcing, but not developing, CT skills. This idea will be further discussed in the following section.

Teaching and Learning Programming in Schools

Barr and Stephenson (2011) argued that today's students will live and work in a world that is heavily influenced by computing principles. In the midst of this trend, CT has become a prerequisite skill for many endeavors of the 21st century. It is a skill that empowers students and thus it is highly beneficial for them to be competent in CT (National Research Council [NRC] 2010). Given that CT is permeating several fields in which most of the students will develop an undergraduate program, it is important to introduce these concepts in schools. Specifically, CT concepts should appear as early as in elementary school, and continue through secondary school and beyond (Qualls & Sherrel, 2010). In this section, we will discuss the different strategies that have been proposed to teach CT in an effective way (using programming as the central core of computer science) to elementary and high school students.

Three psychological theories have been put forward to explain the most effective ways of teaching: objectivism, cognitivism, and constructivism (Luo, 2005). Briefly, objectivism describes the world as an environment made up of objects and proposes that learning is grounded in observation, a process to create corresponding representations of these objects in the minds of learners (Lakoff, 1987). Cognitivism focuses on how human memory works to promote learning. It considers learning as "involving the acquisition or reorganization of the cognitive structures through which humans process and store information" (Good & Brophy, 1990, p. 187). Finally, Ben-Ari (2001) contended that the dominant theory of learning in all the areas of knowledge, including CT, is the constructivism. This theory proposes that knowledge is actively constructed by the student using experiences and previously acquired knowledge, and not passively absorbed from textbooks and lectures. Furthermore, the Ben-Ari claimed that in terms of CT, passive learning will likely fail because each student brings a different cognitive framework to the classroom, and each student will construct knowledge in a different way. Thus, learning must be active; the student must construct knowledge assisted by guidance from the instructor and feedback from other students.

Based on a constructivist approach, programming has been suggested as the main strategy to address CT in schools (Hromkovic, 2006; Wing, 2006). Although CT is broader than programming, the latter is a central process for CT. Programming encourages creativity, logical thinking, precision, and problem solving, and helps improve the personal, learning, and thinking skills required in the modern school curriculum (NRC, 2010). Generally, programming is taught using programming

languages; nevertheless, teaching programming to elementary and high school students can be extremely difficult. Linn (1985) stated an ideal chain for learning computer programming, which gradually goes from program comprehension and ends with program generation, based on lectures and practical exercises. The chain has three main links: Single Language Features, Design Skills, and General Problem-Solving Skills (Saeli et al., 2011). According to Linn, the ideal chain should start with the understanding of the language features, knowledge that can be assessed by asking students to reformulate or change a language feature in a program so that the program does something different (Saeli et al., 2011). The second link of the chain consists of design skills, which are a group of techniques used to combine language features to form a program. The third link of the chain is useful for learning new formal systems. Asking students to solve problems using an unfamiliar formal system such as a new programming language can help transmit problem-solving skills (Saeli et al., 2011). Although this chain of cognitive accomplishment requires an extensive amount of time, it forms a good summary of what could be meant by deep learning in introductory programming (Robins et al., 2003).

Even if the previously mentioned approach to teach programming has been well-described and widely used, introductory courses of programming in schools, called CS0 (Computer Science 0) and CS1 (Computer Science 1) may have as high as a third of the students failing the course when only using lectures and lab-based exercises (Bennedsen & Caspersen, 2007). A recent study showed that despite the advances in pedagogy, research, and application, students still fail in trying to learn programming, and more important, the course failure rates are not yet, substantially influenced by aspects of external teaching context, such as the programming language taught in the course (Watson, 1997). In other words, the problem might not be the language used to teach programming, but the teaching intervention approach used to reach the attention and interest of the student as well as the support provided in the process.

Challenges Faced by Early Programmers, Programming Languages, and Pedagogical Tools Used in Schools

Over the past 15 years, in most of the schools where programming is taught, programming languages that are professional in nature (such as C, C++, and Java) are used as the main tool for teaching based on the availability of engineers able to teach the course, online material, and third-party vendors who provide support around the world (Costa & Aparicio, 2014; Grandell, Peltomaki, Back, & Salaskoski, 2006). However, these languages have extensive and complex syntaxes, leading to great difficulties for beginners (Jenkins, 2002). The methodology involves traditional teaching methods, normally based on lectures and specific programming language syntaxes, in combination with guides and computer lab sessions (Bennedsen & Caspersen, 2007). Nevertheless, these approaches often fail in motivating students and in getting them involved in deep programming activities (Lahtinen et al., 2005; Schulte & Bennedsen, 2006).

One of the difficulties faced by novice programmers include dealing with the verbosity in specialized programming languages, which makes it harder for them to learn algorithmic thinking (Grandell et al., 2006). Novice programmers have to

deal with abstract concepts. They need to understand a given problem, identify the steps to approach such problem, and be able to design a solution. Students should know how to subdivide a given solution into easy and simpler pseudo-code and ought to be able to conceive hypothetical error situations in order to test their programs and find possible missteps (Esteves, Fonseca, Morgado, & Martins, 2008). Furthermore, novice programmers have difficulties understanding even the most basic concepts in programming such as variables, data type, machine structure, and functioning, given that there are no real-life analogies related to these concepts (Lahtinen et al., 2005; Miliszewka & Tan, 2007). Last, even after understanding the basic concepts in programming, programmers must learn the specificities of the programming language they intend to use (Lahtinen et al., 2005; Winslow, 1996).

Another important fact that should be considered as a major challenge in learning and teaching programming is the low enrollment and interest of women in computer science courses and programs. Researchers have identified a variety of factors that may contribute to this issue. These factors include concerns about the computing culture, lack of encouragement from peers (Kelleher, Paushc, & Kiesler, 2007), lack of motivation, and gender stereotypes (Doube & Lang, 2012). Extremely strong school stereotypes are held in STEM (science, technology, engineering, and mathematics) fields, including computer science, where females have a lower self-concept of ability than males ranging from an early age (Denissen, Zarett, & Eccles, 2007) to postgraduate studies (Cohoon & Asprey, 2006), despite an equivalent and sometimes higher level of achievement (Eccles, 2007).

In the STEM field of computing, females have significantly less confidence than males in their ability to learn and succeed (Singh, Allen, Scheckler, & Darlington, 2007). Furthermore, there is a widespread perception that computer experts are socially isolated "geeks" or "nerds" obsessed with technology, a way of living that does not match with most women (Margolis & Fischer, 2002) who tend to be more socially oriented (Herring, Christine, Ahuja, & Robinson, 2006). Doube and Lang (2012) showed that when a course related to computing was removed from the School of Science and placed in the School of Humanities, not only was the female enrollment higher but women also reported enjoying the course and finding applicability to their careers. These authors concluded that there is a psychological aversion in females due to male stereotyping in computing discipline, which is also observed in mathematics, science, and other disciplines (Lang, 2002). Furthermore, females in high school have indicated that their disinterest in computing disciplines arose from their classroom experiences, where they faced isolation, low confidence, felt underrated, and extremely anxious (Pau, Hall, & Grace, 2011). To address some of these issues, students from Computer Science and Information Technology, have developed educational videos that enhance learning experiences related to computer programming in a friendly and familiar environment for women (Ali, 2016; Ali, Raza, & Ali, 2016.).

Despite the difficulties associated with learning programming in school, which are not easy to solve, we strongly agree with Jeannette Wing's (2006) vision that CT is an extensive framework of concepts, abilities, and skills that young people should learn in schools. We also agree with Serafini (2011) that learning

programming on an adequate level of abstraction is a very effective didactic approach to CT, independent of the age of the learners. Hence, we decided to gather, classify, and describe below the most powerful and useful tools available to start the immersion of novices in programming.

Virtual approaches: Logo, scratch, and python as alternative languages for beginners. *Logo* is a mini-language, and in contrast to general-purpose programming languages, it was explicitly developed for teaching programming (Hromkovic, 2006). To write and run programs, novices should not have to deal with the complexity of an extensive general-purpose programming language such as C, C++, and Java (Brusilovsky, Calabrese, & Miller, 1998). Logo editors do not rely on a click-and-drag approach allowing the students to type the instructions by themselves. This makes students care for the correct syntax and allows them to practice debugging (Serafini, 2011). Additionally, the open-source programming environment of XLogo (Le Coq, 2010) presents some interesting features; it runs on multiple platforms, no Internet connection is needed, runs quite well on slow computers and is free, encouraging its use as an introductory tool for programming in schools (Serafini, 2011). Furthermore, teaching materials are available free of charge designed as didactic guidelines and exercises to support teachers (Hromkovic, 2006).

Scratch is a media-rich programming environment developed by MIT's Media lab (https://scratch.mit.edu). It allows students to create animations, games, and interactive art through programming using a computer mouse. The instructions (or code pieces) can be represented as puzzle pieces that only fit one below the other if they are syntactically correct (Malan & Leitner, 2007). Scratch is proposed to be a first language for beginners in introductory courses. It was designed to be user friendly, for all ages, backgrounds, and interests. By using Scratch, students are encouraged to program their own interactive stories, video games, animations, and simulations, and are able to then share their creations with others (Resnick, Maloney, Rusk, & Kafai, 2009). Scratch shows several advantages for introductory programming courses for freshmen students. It allows the instructor and the users to avoid syntax issues (e.g., semicolon use), and thus, allows them to focus on fundamental programmatic constructs (e.g., conditions, loops, variables). Scratch is able to run as a virtual machine in Linux, Mac OS, UNIX, and Windows. It has a version for kids (called Scratch Junior) and offers a great amount of pedagogical material online for free (Malan & Leitner, 2007). In general, most of the students (76%) that are exposed to Scratch, claim a positive influence on their subsequent experiences with specialized languages such as Java (Resnick et al., 2009).

Python is a high-level scripting language designed by Guido van Rossum to facilitate learning (van Rossum, 1999). Van Rossum suggested that any student could become an expert in programming by using python. The use of Python as a starting programming language, allows novice students to get easily involved into the main characteristics of CT (e.g., solving problems and thinking algorithmically (Grandell et al., 2006). This is mainly due to (a) the small, intuitive and clean syntax used in Python compared with languages such as Java or C++; (b) the dynamic typing (variables do not need to be declared) which reduces the notation;

(c) the immediate feedback of potential errors; (d) the enforced structural design that leads the programmer to an indented and structured way of writing; (e) and finally, Python is a free and widely used language that comes with a specially designed text editor, tutorials, books, course material, exercises, and assignments available on the Web.

Real life experiences: LEGO® and LEGO® Mindstorms robot. According to Hood and Hood (2005), the use of LEGO® bricks is a powerful method for teaching programming and language concepts. The combination of colors and positions help indicate specific actions that lead to the learning and development of a set of sequenced instructions, algorithmic thinking, and problem-solving strategies, all, critical skills in CT. Moreover, whereas the LEGO® brick approach does not directly involve technology, it allows the participation of a more inclusive audience given that it evades the intimidation related to the use of computers (LEGO Dacta A/S, 2007). Another advantage of using LEGO® bricks to teach programming, is that a base plate and different-shaped LEGO® blocks are easily acquired. A knowledgeable instructor can design multiple exercises and provide clear instructions by using a single base plate for each participating student or team (Hood & Hood, 2005).

The educational robots of the LEGO Company (LEGO Mindstorms "LM"; http://mindstorms.lego.com/) have been broadly used for introducing programming to novice students (Dagdielis, Sartatzemi, & Kagani, 2005; Hussain, Lindh, & Shukur, 2006; LEGO & A/S, 2007). This approach is inspired on the Constructionism learning theory (Papert, 1993), where students are able to construct the knowledge for themselves. Lego Mindstorms are easily programmable robots that contain a broad variety of bricks, sensors, and motors. These robots can be programmed by using proper software environments to execute different kinds of orders, and most importantly, to react to different stimuli received through their sensors (Atmatzidou, Markelis, & Demetriadis, 2008). By using these educational robots, students learn by playing, creating new knowledge based on a preexisting one (Hussain et al., 2006; LEGO Dacta A/S, 2007).

There are several advantages correlated to the use of LM in introductory programming courses. By using the LM educational robots, students learn through direct observation of their robots operating and interacting in the real world. Students can see when they have made a mistake given that the robot may fall off from a table, crash into a wall, or not interact with environmental conditions. This stimulates them to create robust, expanded, complete, and correct programming, and to invest a huge amount of time debugging programs (Lawhead, Bland, & Schep, 2003). Furthermore, the use of LM robots reduces the fear factor of using computers even if the student had had no previous exposure to playing with LEGO® bricks as a child (Lawhead et al., 2003). Huang, Yang, and Cheng (2013) showed that students who used LM to design and build an artifact as a mean to learn basic concepts, performed better in standardized programming tests in comparison with students who learned using standard methods such as flowcharts. Atmatzidou et al. (2008) stated that the engagement of children during a course that used LM educational robots greatly contributed to the understanding of programming concepts (such as

counter, flag, repetition), leading to the familiarization of structured programming principles.

Virtual life experiences: Game-programming. Video games have been widely used in introductory programming courses as an engaging tool to teach computer science, graphics, software engineering, and network topics (Al-Bow, Austin, & Meyer, 2009). Researchers and educators at schools are confident that this tool can be very helpful in the immersion of novices into programming (Rodger, Hayes, Lezing, & Slater, 2009). As Al-Bow et al. (2009) highlighted, the number of papers suggesting the use of video games in introductory programming courses is quite large as it can be further noted in recent proceedings of conferences such as ACM SIGGRAPH Sandbox, Future Play, Conference on Game Development in Computer Science Education, and Foundations of Digital Games.

An example of video game programming is Alice (Conway, Audia, Burnette, & Christiansen, 2000). This educational software uses an innovative programming environment to create 3D animations using drag-and-drop programming as well as a language that is closely related to objects in Java. In this software, each property, method, and function is attached to an object, with the world being the global object. A variation of Alice, known as Storytelling Alice was created by Caitlin Keller (Kelleher et al., 2007) to encourage middle school students, in particular middle school girls, to learn programming through the creation of short 3D animated movies. Students are able to better understand a variety of programming concepts (e.g., abstraction, modeling, control structures, handlers) by using Alice to make games (Werner, Campe, & Denner, 2012) and stories (Kelleher et al., 2007).

A second example of video gaming as an introductory strategy to programming is the Greenfoot environment (www.greenfoot.org). This visual and interactive software has been specially designed to be simple and easy to use for beginners. Greenfoot includes tutorials that provide the necessary Java concepts (such as inheritance, abstraction, and data binding) to create 2D games (Greenfoot Team, 2009). In a summer camp organized for 14- and 15-year-old students (supported by the NSF and Electronic Arts®), the use of computer games such as Greenfoot was used to integrate computer science and art design instruction through a project-based model methodology. This approach, led to a significant improvement in self-confidence and computer programming knowledge (Al-Bow et al., 2009).

A third example of an educational gaming environment for teaching and learning programming is Pex4Fun (from Microsoft Research; http://www.pexforfun.com/). This web-based tool, allows students to edit code in any browser, to create or manipulate games, and then execute and analyze the game in the cloud (Tillmann & de Halleux, 2011). Pex4Fun is able to find interesting and unexpected input values that help students understand what the code is actually executing. This educational gaming environment, permits a connection between teachers and students by tracking and streaming progress updates in real time. Pex4Fun has been used to teach and learn software engineering from high school all the way through graduate school courses (Tillmann & de Halleux, 2011).

The last example for video gaming learning is the Hour of Code. Code.org® is a nonprofit organization launched in 2013, and Hour of Code was created in

collaboration with engineers from Microsoft, Google, Twitter, and Facebook. The Hour of Code web page was created with the goal of increasing computer science in schools as well as encouraging participation of women and underrepresented students of color in this discipline of study (Code.org®, 2013). The strategy is based on learning basic coding principles through gameplay, using an extensive set of tutorials (called the hour of code) containing practice exercises, lectures, and videos designed by technologists including Bill Gates and Mark Zuckerberg, and artwork from popular games like Angry Birds (Rovio) and Plants vs. Zombies (PopCap Game). According to the creators, more than 10 million people have tried the hour of code (48% female). Among the surveyed teachers who have signed up to teach the intro courses, 99% (almost 115,000) recommend implementing the website resources into computer science curricula (Code.org®, 2013). Last, one additional advantage is that tutorials can be implemented online, using a smartphone with or without Internet connection, and free of charge.

Current Status of Teaching Programming in Schools Worldwide

We have identified three main categories to describe the situation of teaching programming in different countries. These categories are (a) countries where programming is taught as a core course within computer science based on a national curriculum; (b) countries where programming is taught as a tool related to ICT, but major changes are on the way; and (c) countries where programming is taught as a tool merely related to ICT.

Countries where programming is taught as a core course within computer science. According to Diagiene, Jevsikova, Schulte, Sentance, and Thota (2013), Germany and Israel are the countries where a strong curriculum in computer science (CS) is well established. This curriculum includes problem solving, programming, as well as other skills related to CT. In primary and secondary schools in Germany, students are exposed to robotics and HTML as an introduction to the main topics related to CS in parallel with a strong focus on privacy and ethics. High schools in Germany place a strong emphasis on computer programming and computational theory to develop higher skills related to CS.

Israel on the other hand, has developed and implemented a model for a high school CS education program based in four pillars: (a) National CS curriculum and syllabus, (b) Research in CS education, (c) CS teacher preparation programs, and (d) Mandatory CS teaching license (Hazzan, Gal-Ezer, & Blum, 2008). Moreover, students interested in CS take five modules over a 2- to 3-year period, which includes (a) Fundamentals 1 and 2 that introduce central concepts in algorithmic thinking and how to apply them in programming; (b) software design that introduces data structures, abstract data structures, and designs of complete systems; (c) second paradigm that introduces object-oriented languages, programming logic, or functional programming; (d) applications that are focused on computer graphics, management information systems, or Internet programming; and (e) theory that exposes the students to selected topics in theoretical CS such as models of computation and finite automata. Additionally, in both countries, there is a strong focus on teacher training, ranging from CS bachelor degrees to

extensive pedagogical training certified by the Ministry of Education of each country.

Countries where programming is taught as a tool for the information and communications technology field, but major changes are on the way. There are several countries in which programming has been taught for an extensive period of time (5 to 20 years) as part of a program where students are exposed mainly to the syntaxes of a specific programming language with no clear intention in developing skills related to CT. However, thanks to the efforts of the CS teacher's associations and other individuals related to the computer science field, major changes will become visible in the upcoming future (Jones, 2011). The CS associations in the United Kingdom (http://www.computingatschool.org.uk), the United States (http://www.csta.acm.org), and France (http://www.academie-sciences.fr) have been working on promoting and highlighting the importance of teaching programming as a core course in schools.

The Computing At School (CAS) association in the UK released a document (Jones et al., 2013) where they present a review of the CS/ICT curriculum. Several suggestions related to teaching CS, teacher training, and implementation were proposed in view of changing the way how CS is being taught in schools throughout the UK. Moreover, a national curriculum has been proposed in 2013 with the aim of ensuring that students in the UK would be able to understand and apply logic and algorithmic thinking, data representation, and communication as well as analyze and solve problems, and evaluate and apply information technology. This curriculum is under revision at the moment and will hopefully be implemented in the near future (Jones et al., 2013).

In the United States, major events have happened in the past 5 years. The National Science Foundation (NSF) has launched a program called computing education for the 21st century. Numerous companies and associations including the Association for Computing Machinery (ACM), Microsoft, Google, Facebook, Twitter, and other partners have developed a coalition called Computing in the Core with the aim of promoting research in CS teaching. Furthermore, they have developed a platform to attract children into programming and CS in general (Stephenson & Wilson, 2012). The Computer Science Teacher Association (CSTA; 2011) has released a revised K-12 CS standards focused on algorithmic and CT concepts.

In France, the French Academy of Sciences released a report in 2013 (French Academy of Sciences, 2013) claiming that a full review of the ICT/CS curriculum has been made with the support of the government. This ICT/CS curriculum for primary, middle, and high school, aims to achieve a competitive task force in the future. Briefly, students from primary school are dedicated to develop skills related to CT by using appropriate programming languages for their age. This allows them to discover by themselves the main features of algorithmic thinking and problem solving. Later, students from middle school are encouraged to acquire specific concepts related to programming (i.e., syntax) as well as to solve problems on their own, by combining topics in science with programming skills to perform specific tasks. Finally, students in high school work in the strengthening of concepts learned in the earlier two stages, offering the opportunity to

introduce advance constructions such as functions, recursion, dynamic allocation, types of data and objects, and parallelism.

In countries such as Finland, Canada, Scotland, Singapore, South Korea, Japan, Greece, and India, there are curricula that include concepts related to CT and ICT. However, the creation of updated drafts of curricula that intend to include learning of CT skills through programming are on the way with the purpose of increasing the number of students in STEM disciplines (Jones, 2011; Sturman & Sizmur, 2011).

Countries where programming is taught as a tool merely related to the information and communications technology. Due to the lack of well-documented information and well-established associations in countries not mentioned above, it is not unreasonable to assume that most countries are dealing with a situation very similar to that of New Zealand and most countries in Latin America (Jones, 2011). In these countries, computing in school curricula is often ignored, probably due to the fact that computers are used as a tool for teaching (e.g., for web browsing), for general applications related to ICT (e.g., use of Microsoft office), or as a discipline without clear guidelines or purposes regarding CT skills (e.g., learning the syntax of a specific programming language (Jones, 2011).

In Colombia, there are no clear guidelines provided by the government related to CT or CS. Most of the guidelines related to technology focus on the creation of passive users of technology, where students are exposed to a handful of applications with no clear purpose with regard to the development of skills. However, in some private schools, minor changes are occurring. In the last Technology for Education meeting held in Colombia (http://csfr.edu.co/index.php/teb-innovation-time-2015/), besides discussing tools for teaching ICT, some private schools expressed that they have been teaching programming for a while with the purpose of introducing CT skills. Moreover, they spoke about issues related to algorithmic thinking, problem solving, debugging, and other thinking skills. This has motivated them to reevaluate the curricula and to think about ways in which programming is being taught. A couple of schools expressed their intentions of including CS as an official course within their curricula to develop skills associated to CT.

Furthermore, some organizations such as Eduteka (www.eduteka.org) are working on initiatives to expose children to CS and CT. This nonprofit organization, teaches programming via Scratch (Malan & Leitner, 2007) by using mental maps and Venn diagrams. Eduteka also works on strategies to increase the number or girls interested in programming. Another organization from Universidad Nacional de Colombia, developed ProBot (Moreno & Montaño, 2009), a videogame-like application with the purpose of motivating students and engaging them in programming via a boxing-contest environment. Finally, the educational section of RoboCol (an organization in the Department of Engineering of Universidad de los Andes focused on the design and construction of robots for contests; https://robocol.uniandes.edu.co/) teaches programming to kids in elementary schools using the robots of Lego Mindstorms®.

Discussion

It is clear that computers are present in all areas of society, creating an important link between the world's economy and technology and innovation. The

impact of CS on multiple fields within the industry, science, communications, humanities, and society in general is becoming more important. Hence, it is crucial to educate our students not only in the passive understanding and application of digital technology but also to teach them the most important principles of how computers work. In other words, we believe that students should learn the key foundations of CS, given that the skills related to CT could be very helpful in any career at any stage.

However, in order to achieve these goals, the teaching and learning of CS must be centered and focused around CT. The development of skills related to CT such as algorithmic thinking, logic, abstraction, problem solving, debugging, among others, should be the fundamental purpose of CS courses. Moreover, it is important to recall that CS means more than solely learning to program in a specific language, such as Java or C++. Even if programming is central in computing and CS, programming must be taught in light of the development of skills related to CT, instead of a passive use of syntax.

Taking into account all the interventions, points of view, and reports analyzed in this review, it is clear that there are several issues for novice students participating in introductory courses in CS and programming. Despite the different strategies implemented to support these novice students (ranging from collaborative team works, peer tutors, pre-introductory programming courses, exercises and workshops, virtual platforms, virtual tutors, and forums, to changes in the grading system, programs, and curriculum) multiple adversities are still present when students are confronted to algorithmic thinking, logic, debugging, and problem solving; which in turn are the most important skills related to CT. Furthermore, these difficulties, in combination with the exhausting labor of learning syntax, generally leads to frustration, rejection, and poor visions of what programming is, driving most novices away from CS-related careers.

Consequently, as mentioned in several articles referenced in this review, we believe that skills related to CT must be taught at primary, middle, and high school, in order to initiate the cognitive development of students at an earlier age. CS should be recognized as a discrete subject in schools as is math, biology, or social studies. Numerous strategies and initiatives that seek to facilitate the learning and teaching of CT in schools have been developed and put into practice during the last decade. Most of these initiatives aim to replace current practices that use technology in a passive way.

Future Directions

It is important to mention that there is a critical gap in terms of educational research focused on teaching and learning CS and programming. Despite the significant number of articles written by computer scientists that investigate issues related to teaching and learning CS and programming, research conducted by experts in the field of education are almost nonexistent in most countries. Because social and cultural factors have a direct impact in learning, they must be taken into account in curricula design. Thus, constructivist, sociocultural, and pedagogical approaches are needed to create curricula that are geared toward the development of CT skills in primary, middle, and high school. These skills will, without a doubt, be fundamental for the vast majority of jobs in the 21st century.

References

Ahmadzadeh, M., Elliman, D., & Higgins, C. (2005). An analysis of patterns of debugging among novice computer science students. *ACM SIGCSE Bulletin*, *37*, 84–88. doi:10.1145/1151954.1067472

Al-Bow, M., Austin, D., & Meyer, S. (2009). Using game creation for teaching computer programming to high school students and teachers. *ACM SIGCSE Bulletin—ITiCSE '09*, *41*, 104–108. doi:10.1145/1595496.1562913

Ali, T. (2016). *From psychology to logic: Learning computer programming in the kitchen*. Retrieved from http://blossoms.mit.edu/videos/lessons/psychology_logic_learning_computer_programming_kitchen

Ali, T., Raza, S. W., & Ali, M. (2016). *Out for shopping: Understanding linear data structures*. Retrieved from http://blossoms.mit.edu/videos/lessons/out_shopping_understanding_linear_data_structures

Atmatzidou, S., Markelis, I., & Demetriadis, S. (2008). *The use of LEGO Mindstorms in elementary and secondary education: Game as a way of triggering learning*. Paper presented at the workshop proceedings of SIMPAR, Venice, Italy. Retrieved from http://www.terecop.eu/downloads/simbar2008/atmatzidou_et_al.pdf

Barr, V., & Stephenson, C. (2011). Bringing computational thinking to K–12: What is involved and what is the role of the computer science education community? *ACM Inroads*, *2*, 48–54. doi:10.1145/1929887.1929905

Ben-Ari, M. (2001). Constructivism in computer science education. *Computers in Mathematics and Science Teaching*, *20*, 45–73. doi:10.1145/274790.274308

Bennedsen, J., & Caspersen, M. E. (2007). Failure rates in introductory programming. *SIGCSE Bulletin*, *39*, 32–36. doi:10.1145/1272848.1272879

Bogden, C. A. (1997). *The use of concept mapping as a possible strategy for instructional design and evaluation in college genetics* (Unpublished MS thesis). Cornell University, Ithaca, NY.

Brusilovsky, P., Calabrese, E., & Miller, P. (1998). Mini-languages: A way to learn programming principles. *Education and Information Technologies*, *2*, 65–83. doi:10.1023/A:1018636507883

Cardellini, C. (2004). Conceiving of concept maps to foster meaningful learning: An interview with Joseph D. Novak. *Journal of Chemical Education*, *81*, 1303–1308. doi:10.1021/ed081p1303

Cardemone, P. F. (1975). *Concept mapping: A technique of analyzing a discipline and its use in the curriculum and instruction in a portion of a college level mathematics skills course*. (Unpublished MS thesis). Cornell University, Ithaca, NY.

Chase, J. D., & Okie, E. G. (2000). Combining cooperative learning and peer instruction in introductory computer science. *SIGCSE Bulletin*, *32*, 372–376. doi:10.1145/331795.331888

Code.org®. (2013). Hour of code kicks off to introduce k-12 students to computer programming. *IEEE Computer Society*. Retrieved from https://www.computer.org/csdl/mags/co/2013/11/mco2013110099.pdf

Cohoon, J., & Asprey, W. (2006). A critical review of the research on women's participation in postsecondary computing education. In J. M. Cohoon & W. Aspray (Eds.), *Women and information technology: Research on underrepresentation* (pp. 137–180). Cambridge: MIT Press. doi:10.7551/mitpress/9780262033459.003.0005

Computer Science Teacher Association. (2011). *Computer science standards*. Retrieved from https://csta.acm.org/Curriculum/sub/K12Standards.html

Conway, M., Audia, S., Burnette, T., & Christiansen, K. (2000, April). *Alice: Lessons learned from building a 3D system for novices*. Paper presented at the proceedings of the SIGCHI Conference on Human Factors in Computing Systems, The Hague, *Netherlands*. doi:10.1145/332040.332481

Costa, C. J., & Aparicio, M. (2014, May). *Evaluating success of a programming learning tool.* Paper presented at the proceedings of the International Conference on Information Systems and Design of Communication, Lisbon, Portugal. doi:10.1145/2618168.2618180

Curzon, P., Dorling, M., Ng, T., Selby, C., & Woollard, J. (2014). *Developing computational thinking in the classroom: A framework*. Retrieved from http://eprints.soton.ac.uk/id/eprint/369594

Dagdielis, V., Sartatzemi, M., & Kagani, K. (2005, July). *Teaching with robots in secondary schools: Some new and not-so-new pedagogical problems*. Paper presented at the proceedings of the Fifth IEEE International Conference on Advanced Learning Technologies, Kaohsiung, Taiwan. doi:10.1109/ICALT.2005.255

De La Mora, N., & Reilly, C. F. (2012). *The impact of real-world topic labs on student performance on CS1*. Paper presented at the Frontiers in Education Conference, Seattle, WA. doi:10.1109/FIE.2012.6462329

Denissen, J., Zarett, N., & Eccles, J. (2007). I like to do it, I'm able, and I know I am: Longitudinal couplings between domain-specific achievement, self-concept, and interest. *Child Development*, *78*, 430–447.

Diagiene, V., Jevsikova, T., Schulte, C., Sentance, S., & Thota, N. (2013, March). *A comparison of current trends within computer science teaching in school in Germany and the UK*. Paper presented the 6th International Conference ISSEP, Oldenburg, Germany. Retrieved from https://publishup.uni-potsdam.de/opus4-ubp/frontdoor/deliver/index/docId/6187/file/cid06.pdf#page=65

Doube, W., & Lang, C. (2012). Gender and stereotypes in motivation to study computer programming for careers in multimedia. *Computer Science Education*, *22*, 63–78. Retrieved from http://eric.ed.gov/?id=EJ958969

Eccles, J. (2007). Where are all the women? Gender differences in participation in physical science and engineering. In S. J. Ceci & W. M. William (Eds.), *Why aren't more women in science? Top researchers debate the evidence*. Washington, DC: American Psychological Association. doi:10.1037/11546-016

Esteves, M., Fonseca, B., Morgado, L., & Martins, P. (2008, October). *Contextualization of programming learning: A virtual environment study*. Paper presented at the proceedings of the 38th ASEE/IEEE Frontiers in Education Conference, Washington, DC. doi:10.1109/FIE.2008.4720544

Flowers, T., Carver, C., & Jackson, J. (2004). *Empowering students and building confidence in novice programmers through gauntlet*. Paper presented at 34th ASEE/IEEE Frontiers in Education Conference. doi:10.1109/FIE.2004.1408551.

French Academy of Sciences. (2013). *Teaching computer science in France, tomorrow can't wait*. Retrieved from http://www.academie-sciences.fr/pdf/rapport/rads_0513gb.pdf

Good, T. L., & Brophy, J. E. (1990). *Educational psychology: A realistic approach* (4th ed.): White Plains, NY: Longman.

Grandell, L., Peltomaki, M., Back, R.-J., & Salaskoski, T. (2006). *Why complicate things? Introduction programming in high school using phyton*. Paper presented at the proceeding of the 8th Australasian Conference on Computing Education, Hobart, Australia. Retrieved from http://dl.acm.org/citation.cfm?id=1151880

Greenfoot Team. (2009). *Greenfoot environment and api*. Retrieved from http://www.greenfoot.org

Hazzan, O., Gal-Ezer, J., & Blum, L. (2008). A model for high school computer science education: The four key elements that make it! *SIGCSE Bulletin*, *40*, 281–285. doi:10.1145/1352135.1352233

Herring, S., Christine, O., Ahuja, M., & Robinson, J. (2006). Gender and the culture of computing in applied IT education. In E. M. Trauth (Ed.), *Encyclopedia of gender and information technology*. Hershey, PA: Information Science Publishing. doi:10.4018/978-1-59140-815-4.ch074

Hood, C., & Hood, D. (2005, June). *Teaching programming and language concepts using Legos®*. Paper presented at the proceedings of the 10th annual SIGCSE conference on Innovation and Technology in Computer Science Education, Caparica, Portugal. doi:10.1145/1151954.1067454

Hromkovic, J. (2006). Contributing to general education by teaching informatics. *ACM SIGCSE Bulletin*, *37*, 19–23. doi:10.1007/11915355_3

Huang, K., Yang, T., & Cheng, C. (2013). Engineering to see and move: Teaching computer programming with flowcharts vs Lego robots. *iJET*, *8*(4). Retrieved from http://online-journals.org/i-jet/article/view/2943

Hussain, S., Lindh, J., & Shukur, G. (2006). The effect of Lego training on pupils' school performance in mathematics, problem solving ability and attitude: Swedish data. *Educational Technology & Society*, *9*, 182–194. Retrieved from http://eric.ed.gov/?id=EJ836851

Jakovljevic, M. (2003, September). *Concept mapping and appropriate instructional strategies in promoting programming skills of holistic learners*. Paper presented at the annual research conference of the South African Institute of Computer Scientists and Information Technologists on Enablement through Technology (SAICSIT '03), Johannesburg, South Africa. Retrieved from http://dl.acm.org/citation.cfm?id=954048

Jenkins, T. (2002). *On the difficulty of learning to program*. Paper presented at the 3rd Annual LTSN_ICS Conference, Leeds, England. Retrieved from http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.596.9994&rep=rep1&type=pdf

Jones, S. (2011). *International comparisons*. Retrieved from http://www.csta.acm.org/About/sub/AboutFiles/IntlComparisonsv5.pdf

Jones, S., Mitchell, B., & Humphreys, S. (2013). *Computing at school in the UK*. Retrieved from http://research.microsoft.com/en-us/um/people/simonpj/papers/cas/ComputingAtSchoolCACM.pdf

Kay, D., van der Hoek, A., & Richardson, D. (2005). Informatics: A focus on computer science in context. *ACM SIGCSE Bulletin*, *37*, 551–555. Retrieved from http://www.ics.uci.edu/~andre/papers/C45.pdf

Kelleher, C., Paushc, R., & Kiesler, S. (2007, April). *Storytelling Alice motivates middle school girls to learn computer programming*. Paper presented at the proceedings of the SIGCHI Conference on Human Factors in Computing Systems, San Jose, CA. doi:10.1145/1240624.1240844

Kurland, M., Pea, R., Clement, C., & Mawby, R. (1986). A study of the development of programming ability and thinking skills in high school students. *Educational Computing Research*, *2*, 429–458. Retrieved from http://jec.sagepub.com/content/2/4/429.abstract

Lahtinen, E., Mutka, K., & Jarvinen, H. (2005). A study of the difficulties of novice programmers. *ACM SIGCSE Bulletin*, *37*, 14–18. doi:10.1145/1151954.1067453

Lakoff, G. (1987). *Women, fire and dangerous things*. Chicago, IL: University of Chicago Press.

Lang, C. (2002). Tertiary computing course selection: The impact of mathematics anxiety on female decision making. *AJET*, *18*, 341–358. doi:10.14742/ajet.v18i3.1764

Lasserre, P., & Szostak, C. (2011, June). *Effects of team-based learning on a CS1 course*. Paper presented at the proceedings of the 16th Annual Joint Conference on Innovation and Technology in Computer Science Education, Darmstadt, Germany. doi:10.1145/1999747.1999787

Lawhead, P., Bland, C., & Schep, M. (2003). A road map for teaching introductory programming using Lego© Mindstorms robots. *ACM SIGCSE Bulletin*, *35*, 191–201. doi:10.1145/782941.783002

Le Coq, L. (2010). *Xlogo*. Retrieved from http://xlogo.tuxfamily.org/

LEGO Dacta A/S. (2007). *Study of educational impact of the Lego Dacta materials*. Retrieved from http://www.lego.com/education/download/infoescuela.pdf

Linn, M. C. (1985). Cognitive consequences of programming instruction in classrooms. *Educational Researcher*, *14*, 14–29. doi:10.3102/0013189X014005014

Luo, D. (2005, July). Using constructivism as a teaching model for computer science. *The China Papers*, pp. 36–40. Retrieved from http://science.uniserve.edu.au/pubs/china/vol5/CP5_itcs_02.pdf

Malan, D., & Leitner, H. (2007). Scratch for budding computer scientists. *ACM SIGCSE Bulletin*, *39*, 223–227. doi:10.1145/1227504.1227388

Margolis, J., & Fischer, A. (2002). *Unlocking the clubhouse: Women in computing*. Cambridge: MIT Press.

Miliszewka, I., & Tan, G. (2007). Befriending computer programming: A proposed approach to teaching introductory programming. *Issues in Informing Science & Information Technology*, *4*, 277–289. Retrieved from http://proceedings.informingscience.org/InSITE2007/IISITv4p277-289Mili310.pdf

Moreira, M. (1977). *An Ausubelian approach to physics instruction: An experiment in an introductory college course in electromagnetism* (Unpublished MS thesis). Cornell University, Ithaca, NY.

Moreno, J., & Montaño, E. (2009). Probot: Juego para el aprendizaje de la logica en programación [Probot: Game for learning logic in programming]. *Nuevas Ideas en Informatica Educativa*, *5*, 1–7. Retrieved from http://www.tise.cl/2009/tise_2009/pdf/1.pdf

Mow, C. (2006). *The effectiveness of cognitive apprenticeship based learning environment (cable) in teaching computer programming*. Adelaide, South Australia: University of South Australia.

National Research Council. (2010). *Report of a workshop on the scope and nature of computational thinking*. Washington, DC: National Academies Press. doi:10.17226/12840

Nikula, U., Gotel, O., & Kasurinen, J. (2011). A motivation guided holistic rehabilitation of the first programming course. *ACM Transactions on Computing Education (TOCE)*, *11*, 24–38. doi:10.1145/2048931.2048935

Novak, J. D. (1990). Concept maps and vee diagrams: Two metacognitive tools to facilitate meaningful learning. *Instructional Science*, *19*, 29–52. doi:10.1007/BF00377984

Novak, J. D. (1991). Clarify with concept maps. *The Science Teacher*, *58*, 44–49. Retrieved from http://eric.ed.gov/?id=EJ447816

Novak, J. D. (1998). *Learning, creating, and using knowledge: Concept maps as facilitative tools in schools and corporations*. Mahwah, NJ: Erlbaum.

Novak, J. D., & Afamasaga-Fuata'i, K. (2009). *Concept mapping in mathematics: Research into practice*. Berlin, Germany: Springer eBooks.

Pane, J., & Myers, B. (1996). *Usability issues in the design of novice programming system* (Technical Report CMU-CS-96-132). Pittsburgh, PA: Carnegie Mellon University, School of Computer Science. Retrieved from http://www.cs.cmu.edu/~pane/cmu-cs-96-132.html

Papert, S. (1993). *Mindstorms: Children, computers, and powerful ideas*. New York, NY: Basic Books.

Pau, R., Hall, W., & Grace, M. (2011). "It's boring": Female students' experience of studying ict and computing. *Social Science Review*, *92*, 89–94. Retrieved from http://eric.ed.gov/?id=EJ943938

Pendley, B. D., Bretz, R. L., & Novak, J. D. (1994). Concept maps as a tool to assess learning in chemistry. *Journal of Chemical Education*, *71*, 9–11. doi:10.1021/ed071p9

Piteira, M., & Costa, C. (2012, June). *Computer programming and novices programmers*. Paper presented at the proceedings of the Workshop on Information Systems and Design of Communication, Lisbon, Portugal. doi:10.1145/2311917.2311927

Piteira, M., & Costa, C. (2013, July). *Learning computer programming*. Paper presented at the proceedings of the 2013 International Conference on Information Systems and Design of Communication, Lisbon, Portugal. doi:10.1145/2503859.2503871

Qualls, J., & Sherrel, B. (2010). Why computational thinking should be integrated into the curriculum. *Journal of Computer Science Colleges*, *25*, 66–71. Retrieved from http://dl.acm.org/citation.cfm?id=1747148&dl=ACM&coll=DL&CFID=748545222&CFTOKEN=94380546

R Development Core Team. (2008). *R: A language and environment for statistical computing*. Vienna, Austria: R Foundation for Statistical Computing. Retrieved from http://www.R-project.org

Rankin, Y., Gooch, A., & Gooch, B. (2008, February). *The impact of game design on students' interest in CS*. Paper presented at the proceedings of the 3rd International Conference on Game Development in Computer Science Education, Miami, FL. doi:10.1145/1463673.1463680

Resnick, M., Maloney, J., Rusk, N., & Kafai, Y. (2009). Scratch: Programming for all. *Communications of the ACM*, *52*, 60–67. doi:10.1145/1592761.1592779

Robins, A., Rountree, J., & Rountree, N. (2003). Learning and teaching programming: A review and discussion. *Computer Science Education*, *13*, 137–172. Retrieved from http://home.cc.gatech.edu/csed/uploads/2/robins03.pdf

Rodger, S., Hayes, J., Lezing, G., & Slater, D. (2009, March). *Engaging middle school teachers and students with Alice in a diverse set of subjects*. Paper presented at the proceedings of the 40th ACM Technical Symposium on Computer Science Education, Chattanooga, TN. doi:10.1145/1508865.1508967

Saeli, M., Perrenet, J., Jochems, W. M., & Zwaneveld, B. (2011). Teaching programming in secondary school: A pedagogical content knowledge perspective. *Informatics in Education*, *10*, 73–88. Retrieved from http://www.fing.edu.uy/grupos/nifcc/material/2015/PCK.pdf

Schulte, C., & Bennedsen, J. (2006, September). What do teachers teach in introductory programming? Paper presented at the proceedings of the Second International Workshop on Computing Education Research, Canterbury, UK. doi:10.1145/1151588.1151593

Serafini, G. (2011) Teaching programming at primary schools: Visions, experiences, and long-term research prospects. In: I. Kalaš & R. T. Mittermeir (Eds.), *Informatics in schools. Contributing to 21st century education* (Lecture Notes in Computer Science, Vol. 7013). Berlin, Germany: Springer. doi:10.1007/978-3-642-24722-4_13

Shaffer, S., & Rosson, M. (2013). Increasing student success by modifying course delivery based on student submission data. *ACM Inroads*, *4*, 81–86. doi:10.1145/2537753.2537778

Singh, K., Allen, K., Scheckler, R., & Darlington, L. (2007). Women in computer-related majors: A critical synthesis of research and theory from 1994 to 2005. *Review of Educational Research*, *77*, 500–533. doi:10.3102/0034654307309919

Sleeman, D. (1986). The challenges of teaching computer programming. *Communications of the ACM*, *29*, 840–841. doi:10.1145/6592.214913

Stephenson, C., & Wilson, C. (2012). Reforming k-12 computer science education . . . What will your story be? *ACM Inroads*, *3*, 43–46. doi:10.1145/2189835.2189850

Sturman, L., & Sizmur, J. (2011). *International comparison of computing in schools*. Retrieved from https://www.nfer.ac.uk/publications/cis101/cis101_home.cfm

Syslo, M. (2015, July). *From algorithmic to computational thinking: On the way for computing for all students*. Paper presented at the proceedings of the 2015 ACM Conference on Innovation and Technology in Computer Science Education, Vilnius, Lithuania. doi:10.1145/2729094.2742582

Tew, A., Fowler, C., & Guzdial, M. (2005, February). *Tracking an innovation in introductory CS education from a research university to a two-year college*. Paper presented at the proceedings of the 36th SIGCSE Technical Symposium on Computer Science Education, St. Louis, MO. doi:10.1145/1047344.1047481

Tillmann, N., & de Halleux, J. (2011, May). *Pex4fun: Teaching and learning computer science via social gaming*. Paper presented at the Software Engineering Education and Training (CSEE&T), 2011 24th IEEE-CS Conference. doi:10.1109/CSEET.2012.13

Tu, J., & Johnson, J. (1990). Can computer programming improve problem-solving ability? *SIGCSE Bulletin*, *22*, 30–33. doi:10.1145/126445.126451

Turns, J., Atman, C. J., & Admas, R. (2000). Concept maps for engineering education: A cognitively motivated tool supporting varied assessment functions education. *IEEE Transactions*, *43*, 164–173. doi:10.1109/13.848069

Tuugalei, I., & Mow, C. (2012). Analyses of student programming errors in java programming courses. *Journal of Emerging Trends in Computing and Information Sciences*, *3*, 739–749. Retrieved from http://www.cisjournal.org/journalofcomputing/archive/vol3no5/vol3no5_11.pdf

van Rossum, G. M. (1999). *Computer programming for everybody*. Retrieved from https://www.python.org/doc/essays/cp4e/

Vega, C., Jimenez, C., & Villalobos, J. (2013). A scalable and incremental project-based learning approach for CS1/CS2 courses. *Education and Information Technologies*, *18*, 309–329. doi:10.1007/s10639-012-9242-8

Vihavainen, A., Airaksinen, J., & Watson, C. (2014, August). *A systematic review of approaches for teaching introductory programming and their influence on success*. Paper presented at the proceedings of the Tenth Annual Conference on International Computing Education Research, Glasgow, Scotland. doi:10.1145/2632320.2632349

Villalobos, J., Calderon, N., & Jimenez, C. (2009). *Cupi2 community: Promoting a networking culture to support teaching programming*. Paper presented at the International Conference on Computer Supported Education (CSEDU), Lisbon, Portugal. Retrieved from https://cupintranet.virtual.uniandes.edu.co/site/index.php/el-proyecto-topmenu/unicopublicaciones

Villalobos, J., & Casallas, R. (2006). *Teaching/learning a first object-oriented programming course outside the CS curriculum*. Paper presented at the Tenth Workshop on Pedagogy and Tools for the Teaching and Learning of Object Oriented Concepts, Nantes, France. Retrieved from https://cupintranet.virtual.uniandes.edu.co/site/index.php/el-proyecto-topmenu/unicopublicaciones

Villalobos, J., Casallas, R., & Marcos, K. (2005). *El reto de diseñar un primer curso de programación de computadores* [The challenge of designing a first course in computer programming]. Paper presented at the XIII Congreso Iberoamericano de Educación Superior en Computacion, Cali, Colombia. Retrieved from https://cupintranet.virtual.uniandes.edu.co/site/index.php/el-proyecto-topmenu/unicopublicaciones

Watson, C. (1997, February). *Collaborative learning: A case study for CS1 at Grinnell College and Austin*. Paper presented at the proceedings of the twenty-eighth SIGCSE Technical Symposium on Computer Science Education, San Jose, CA. doi:10.1145/268084.268164

Werner, L., Campe, S., & Denner, J. (2012, February). *Children learning computer science concepts via Alice game-programming*. Paper presented at the proceedings of the 43rd ACM Technical Symposium on Computer Science Education, Raleigh, NC. doi:10.1145/2157136.2157263

Werner, L., Denner, J., Campe, S., & Kawamoto, D. (2012, February). *The fairly performance assessment: Measuring computational thinking in middle school*. Paper presented at the SIGCSE '12 Proceedings of the 43rd ACM Technical Symposium on Computer Science Education, Raleigh, NC. doi:10.1145/2157136.2157200

Williams, L., McDowell, C., Nagappan, N., Fernald, J., & Werner, L. (2003, September). *Building pair programming knowledge through a family of experiments*. Paper presented at the ISESE '03 Proceedings of the 2003 International Symposium on Empirical Software Engineering, Washington, DC. Retrieved from http://dl.acm.org/citation.cfm?id=943642

Wing, J. (2006). Computational thinking. *Communications of the ACM*, *49*(3), 33–35. doi:10.1145/1118178.1118215

Winslow, L. (1996). Programming pedagogy—A psychological overview. *SIGCSE Bulletin*, *28*, 17–22. doi:10.1145/234867.234872

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Recruitment	Chad Eickhoff	Director, University Admissions
	Dan Palm	AVP, Center for International Education
	Eric Deschamps (for Dan Palm)	Director, Center for International Education
	Jane Kuhn	Vice President, EM
	Kathy Yeager	AVP, Educational Partnerships
	Margot Saltonstall	AVP, Enrollment Management
	Maribeth Watwood	Dean, Graduate College
	Gayla Stoner	Dean, NAU Online
	Mike Sabath	Ass VP & Cmps Exec Ofcr NAU-Yuma

Price Positioning	Bjorn Flugstad	VP, Finance, Inst Planning & Analysis
	Christy Farley	VP, External Affairs & Partnerships
	Dan Okoli	VP, Capital Planning/Campus Ops
	Jane Kuhn	VP, Enrollment Management
	Joanne Keene	Executive Vice Pres, Chief of Staff
	Laura Jones	Chief Institutional Data Officer
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	Dylan Rust	Director, Center for Intern'l Education
	Eddie Waters	Director, VPAA: Business Analysts
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	Evin Deschamps	Director, Academic Success Centers
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	Ivy Banks	Director, Indigenous Student Success
	JJ Boggs	Director, Transfer & Online Connections
	Joey Ruiz	Program Director, SA Mentoring
	John Masserini	Vice Provost – Academic Affairs
	Kyle Cawood (per Stalker)	Systems Analysis, Team Lead
	Laura Jones	Chief Institutional Data Officer
	Laurie Dickson	Vice Provost-TLDA
	Margot Saltonstall	AVP, Enrollment Management
	Melissa Welker	Exec Dir, Undergraduate Retention
	Michael Kallsen	Associate Athletic Director
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	Monica Bai	Director, Gateway Student Success Ctr
	Sue Belatti	Director, Residence Life
	Terri Hayes	Executive Director, University Advising
	Traci Harvey	Director, First-Generation Programs
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University Marketing	Harlan Teller	Chief Marketing Officer
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	Maribeth Watwood	Dean, Graduate College
	Gayla Stoner	Dean, NAU Online
	Steve Burrell	Chief Information Officer

EXECUTIVE SUMMARY

ITEM: **Overview of Tuition Pledge Program (NAU)**

☐ Action Item ☐ Discussion Item ☒ Information Item

ISSUE: The Committee will receive a review of the NAU Tuition Pledge Program structure.

BACKGROUND:

- The NAU Pledge Program guarantees entering students a flat rate of tuition for all four years. The program was first approved by the Board in December 2007 and was established to provide a predictable and affordable tuition option.

- The Board asked NAU and the System Office to jointly review the fiscal structure of the NAU Tuition Pledge Program and present the findings to the Business and Finance Committee.

Findings:

- NAU's intent for the Pledge Program is to provide a built-in incentive for students to hold costs down by graduating within the four-year window. Students that do not graduate within four years must pay the same tuition rate of the preceding pledge class.

- Based on survey data and progress in Enterprise metrics, the program is viewed as a marketing success that helps offset the disadvantage of being a residential rural campus. Since the implementation of this option NAU has experienced increased enrollments, retention, four-year graduation rate degrees earned, and student and parent satisfaction.

- The program appears to be fiscally sound based on the considerations factored into development of the tuition pledge rate for each class, and the maintenance of a reserve to cover unanticipated shortfalls in pledge revenue estimates.

DISCUSSION:

- Several Board members have expressed a desire for a better understanding of the fiscal structure of the Pledge Program and asked that the System Office work with NAU to review the structure and determine the fiscal soundness of the program. The answers to the following questions address the issues raised by the Regents:

  1. *How is the annual increase in the PLEDGE rate determined?*

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- Figure A shows a detailed activity flow for the calculation of the tuition proposal.

In summary, the NAU budget office:

- Projects the General Fund appropriation plus Tuition and Fee support per student (operating revenue per student).

- Projects the General Fund appropriation, unbudgeted tuition revenue due to higher than anticipated enrollments, and enrollments by tuition group, i.e. cohort, resident and nonresident.

- Completes an analysis of additional considerations such as increases in recurring expenses, specific campus initiatives, level of expense reductions, as well as enrollment projections for new students and by existing PLEDGE classes.

- Deploys a tuition revenue model to test potential enrollment increase or decline, tuition rate, and financial aid scenarios for PLEDGE, Graduate, and Extended Campus students over a multi-year time horizon.

- The resulting analysis and additional considerations produces varying operating revenue support per student, which are taken into consideration when final tuition rates are proposed.

- The political context is then factored into the final rate proposal, along with economic factors, and the desired per student funding level.

2. *Is it true that NAU needs to increase enrollments and/or the PLEDGE tuition rate each year to maintain the fiscal soundness of the program?*

- The methodology for calculating the new PLEDGE rate each year, looks at the level of expenditures needed in the following year and sets the rate for the incoming class at a level to generate revenue to cover these costs. The tuition revenue per returning student is fixed, thus if costs are projected to increase, increases must be borne by the PLEDGE, Graduate, and Extended Campus classes through increased enrollments, tuition, one-time reserves, or a combination of these options.

3. *How are the reserves generated for future year cost increases?*

- The methodology for tuition setting is a pay as you go model. The methodology does not allow for a reserve or deferral of revenue to cover cost increases in years 2, 3 and 4.

- NAU has sufficient cash reserves and has established a “reserve” or designated fund to backstop a decline in enrollments.

- NAU staff has calculated a reserve based upon the assumption of a one-year 400 FTE decline in resident enrollments. Further, the calculation would include 200 FTE for the second year of a decline.

- The calculated reserve is $16.1 million.

4. *In the event of unforeseen financial challenges, is there a legal obligation to continue the PLEDGE Program?*

- The PLEDGE program is reviewed and recommended on an annual basis for each incoming class. The PLEDGE program for incoming students can be changed or eliminated prior to matriculation of that class.

- The university maintains an obligation to those students who have matriculated under the PLEDGE program to continue the PLEDGE for their class.

- **Staff analysis conclusions:**

  - The ABOR staff reviewed the PLEDGE program and found it to be fiscally sound provided the reserve identified by NAU is designated and maintained.

  - This reserve NAU identified has the effect of increasing their days cash calculation by 15 days which is a legitimate reason to exceed the upper threshold of the liquidity measure policy approved by the Board.

  - The methodology has the result of next year's cost increases being borne by the incoming PLEDGE class and Graduate and Extended Campus students rather than the PLEDGE classes from the prior three years.

    - This is a concept similar to the methodology used by many institutions when financing a new student union or other major expansions.

    - An alternative method would be to anticipate legislative funding levels combined with cost increases over a four year period, and then setting aside a reserve for each class which then covers the projected costs for the last 2 years of their four year education. This method would be more complex to administer and difficult to accurately calculate.

RECOMMENDATION:

This item is for information only. No action is required.

FIGURE A

ABOR Tuition Policy and Guidelines

INITIAL CONSIDERATIONS

- Projection of General Fund Appropriation
- Any unbudgeted tuition revenue related to higher than projected enrollment growth?
- Enrollment Projection by Tuition Group

General Fund + Tuition and Fees Support per Student Goal

ADDITIONAL CONSIDERATIONS

- Projected increases in traditional recurring State or Locally Retained Budget expenditures (benefits, utilities, faculty promotions, debt service, financial aid, student program support
- *Internal Macro Planning Budget Priorities:* Current and new commitments that will be expended in the new fiscal year
- Planned recurring expenditure reductions

TUITION SCENARIO PROJECTIONS

- Tuition Sensitivity Study
- Peer Data on Tuition
- Average 4-year COL/HEPI
- Projected New Entering Flagstaff Undergraduates
- Multi-year forecasts

Population Shares/Tuition Distance from New Entering Pledge Class

- Nonresident UG Student Distance
- Nonresident Graduate Student Distance
- Statewide/Yuma/Yavapai UG Distance
- Resident Graduate Student Distance

General Fund + Tuition and Fees Support per Student Scenario Outcomes

ABOR Tuition Political Context

Tuition Proposal

NORTHERN ARIZONA UNIVERSITY

Business and Finance Committee
Agenda Item #5:

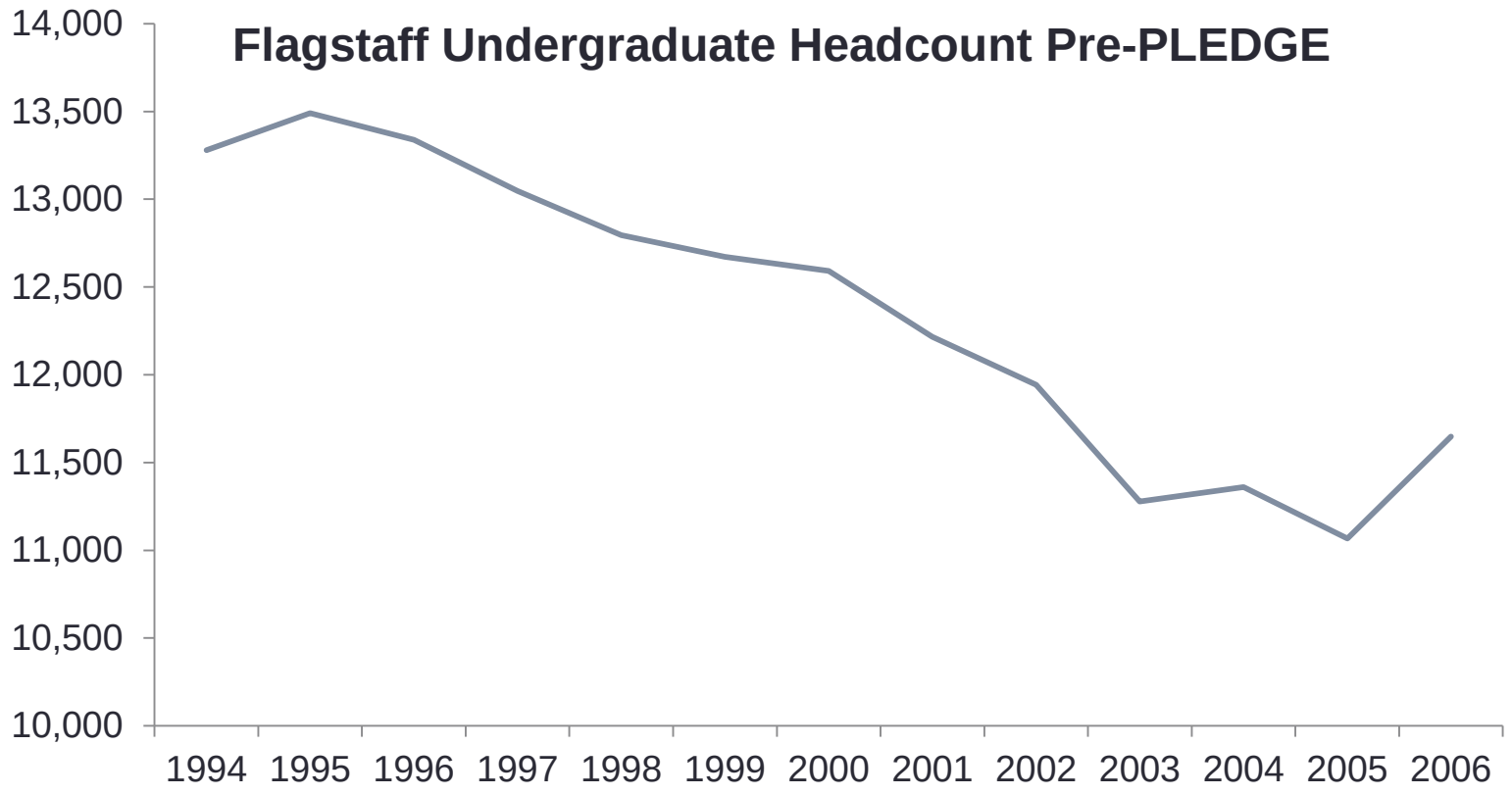
PLEDGE PROGRAM

The Theory Behind the Pledge

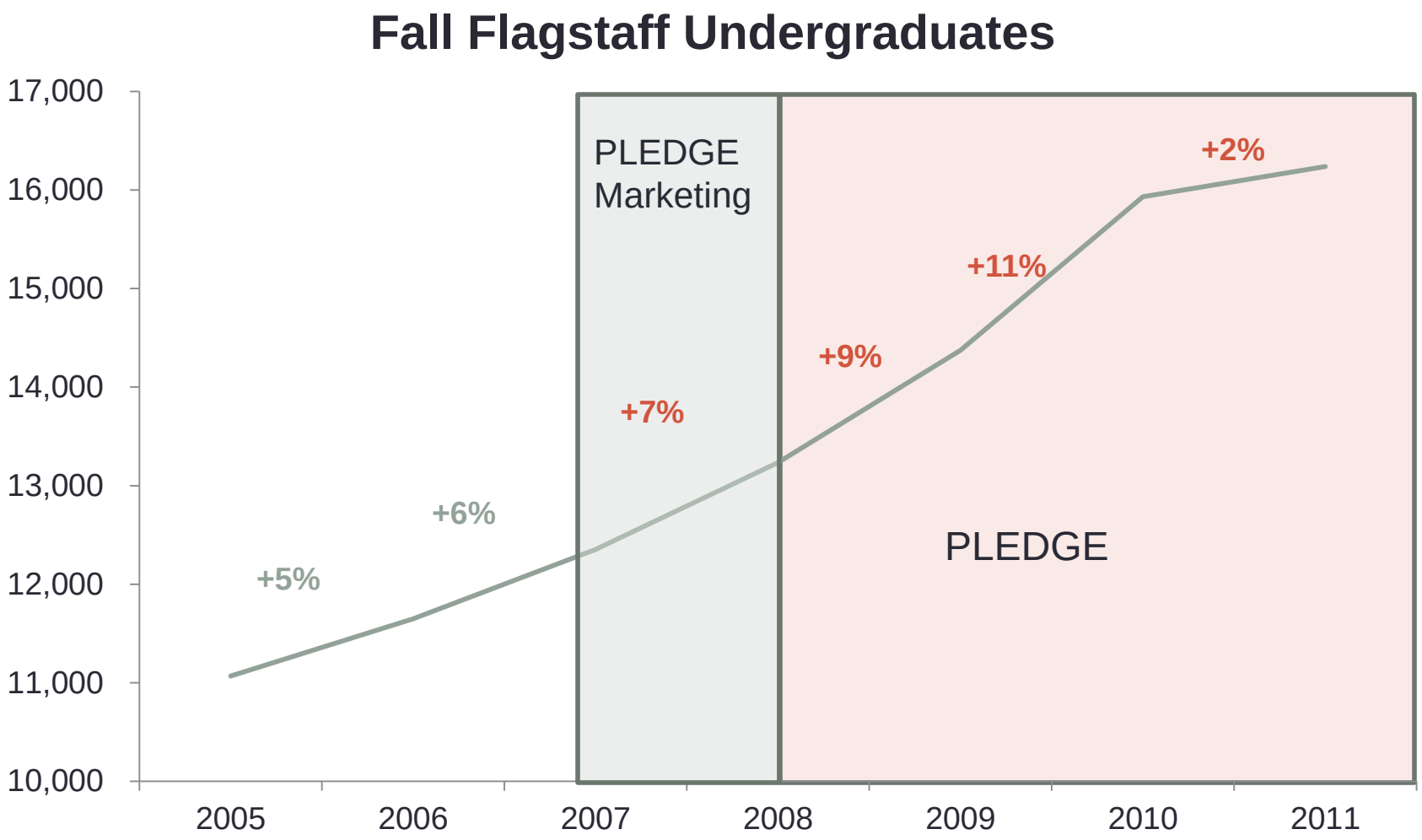
- The Pledge combines tuition with an insurance contract
- The insurance contract guarantees a fixed tuition and as a result transfers risk from the students/family to the university
- Like all insurance contracts, people will pay more than the expected loss to shed the risk
- NAU can diversify the risk less expensively through its budget planning than the family can
- As a result, both the family and NAU are better off

THE PLEDGE AS A MARKETING TOOL

PLEDGE program is a key market edge to offset the disadvantage of a rural campus



Flagstaff Undergraduate Enrollment Post-PLEDGE



Pledge Parent Survey Results – Initial Market Research Fall 2008-2009

- **70%** of parents indicated The Pledge Tuition Program was very important in the decision to attend NAU
  - (Fall 2009 Cohort, 2,597 Respondents)
- **93%** of parents indicated it is very important for them to be able to plan and budget educational expenses
  - (Fall 2009 Cohort, 2,597 Respondents)
- **54%** of parents strongly agree that their students returned to NAU because of the guaranteed tuition rates
  - (Fall 2008 Freshman and Transfer Students, 1,149 Respondents)
- **50%** of students indicated The Pledge influenced their decision to attend NAU
  - (Fall 2009 Cohort, 3,421 Respondents)

2012 Survey Results

- **90%** of parents responded that 4-year **predictability** in tuition costs is **very important**
  - (Fall 2012 Cohort, 1,056 Respondents)
- **77%** of parents strongly agreed that the Pledge makes it possible for their families **to plan for college costs** through to student's degree completion
  - (Fall 2012 Cohort, 1,056 Respondents)
- **66%** of parents strongly agreed the Pledge makes it possible for their families **to know** they can **afford** four years of college for their children
  - (Fall 2012 Cohort, 1,056 Respondents)

Pledge as a Marketing Tool – May 2012 Focus Groups

Students and parents from the Phoenix area and California were asked :

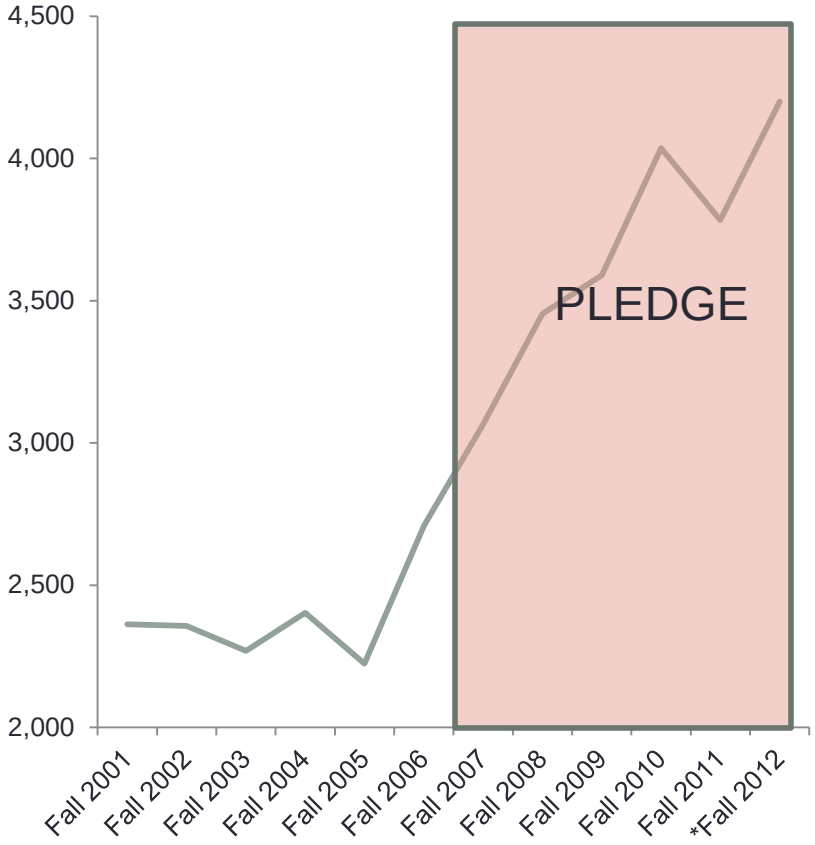
- Would the Pledge program influence your decision to apply to, or attend NAU?
- Would the Pledge program provide you and your family predictability in planning for tuition costs?

RESULTS

- **83%** of parents believe the Pledge program makes NAU more attractive

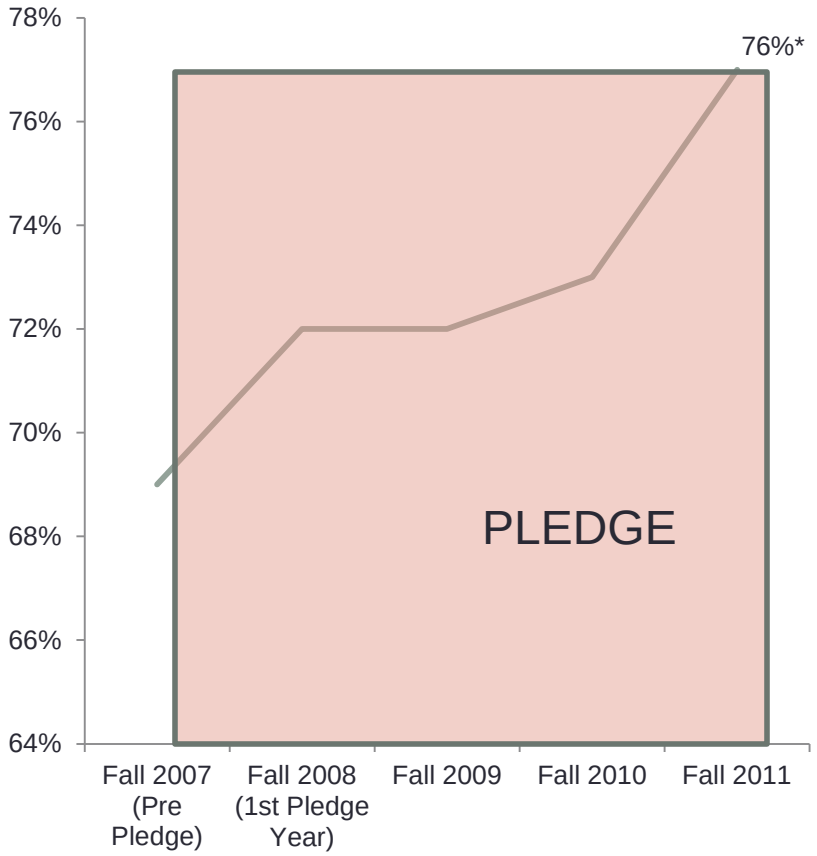
The Pledge as a Recruiting and Retention Tool

Flagstaff First-Time Cohort Headcount



*Estimate

Flagstaff First-Time Full-Time One Year Retention



* As of 9/11/2012

TUITION MODELING

Enrollment by category
- Full-time equivalent %
- Retention rate

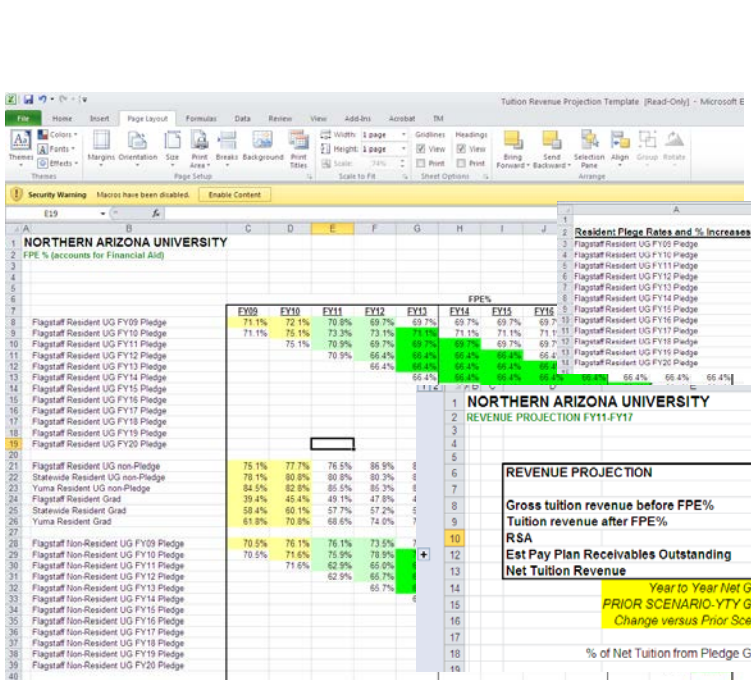
Tuition rates by category

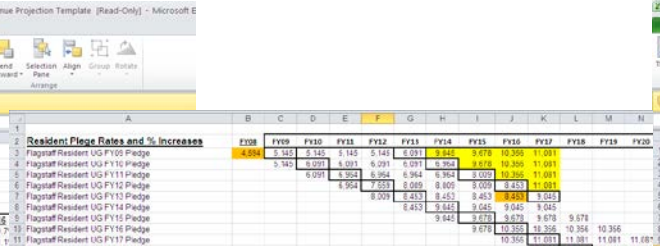
Tuition aid waivers (Full pay equivalent % by category)

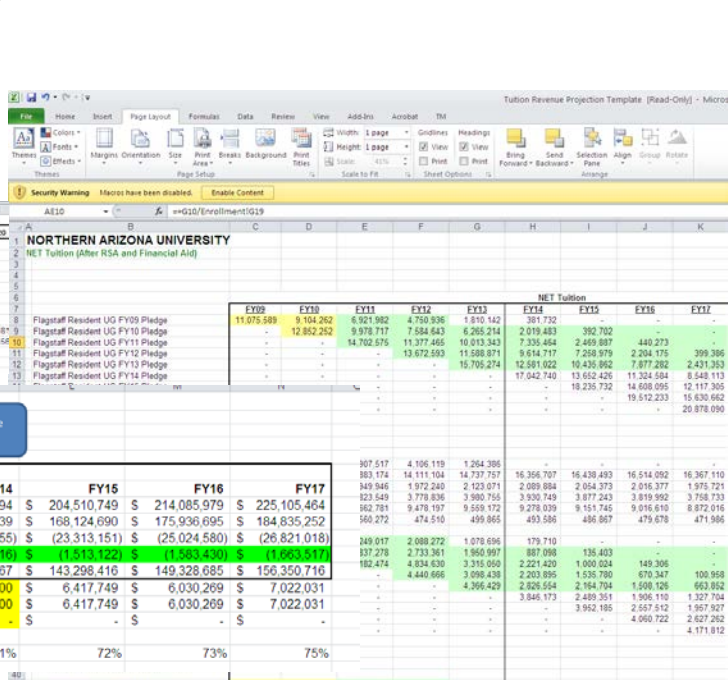
Gross Tuition Revenue

Need-based financial aid (Regent's set aside)

Net Tuition Revenue







TUITION SAFETY NET

PLEDGE Design and Safety Net

- Total Pledge tuition revenue is about 70% of overall tuition revenue (excludes fees); annual increases in graduate and extended campus programs. Fees are additional.
- Annual decision to maintain the Pledge program
- Efficiencies, restructuring options are examined to contain or reduce costs
- Enrollment growth needed to meet 2020 metric goals
- Maintain sufficient liquidity to ensure four-year educational quality regardless of negative impact (of enrollment) on revenue
- PLEDGE reserve for FY13 = $16.1M; additional 15 days cash on hand

Actual Tuition Increase (%):	*5.5%*	*4.9%*	*2.8%*	*3.0%*	*3.0%*	*3.5%*		
Net Tuition (after RSA/Waivers)	**FY13**	**FY14**	**FY15**	**FY16**	**FY17**	**FY18**	**FY19**	**Total FY13 - FY19**
Difference from Proposal and **1.0% incr:**	$ 6,513,435	$ (627,449)	$ (6,132,254)	$ (10,021,836)	$ (13,157,720)	$ (15,427,647)	$ (18,515,292)	**$ (57,368,764)**
Resident UG	3,904,930	79,778	(2,711,071)	(4,573,666)	(5,953,288)	(7,035,596)	(8,409,223)	**(24,698,136)** 43%
	60%	-13%	44%	46%	45%	46%	45%	**39%**
WUE	2,608,505	(707,227)	(3,421,184)	(5,448,170)	(7,204,432)	(8,392,051)	(10,106,069)	**(32,670,628)** 57%
	40%	113%	56%	54%	55%	54%	55%	**61%**
Difference from Proposal and **1.3% incr:**	$ 6,825,964	$ 36,455	$ (5,120,465)	$ (8,637,008)	$ (11,414,041)	$ (13,397,410)	$ (16,141,267)	**$ (47,847,771)**
Resident UG	4,074,377	413,426	(2,227,865)	(3,936,521)	(5,165,623)	(6,119,304)	(7,340,649)	**(20,302,160)** 42%
	60%	1134%	44%	46%	45%	46%	45%	**203%**
WUE	2,751,588	(376,970)	(2,892,600)	(4,700,487)	(6,248,417)	(7,278,107)	(8,800,618)	**(27,545,611)** 58%
	40%	-1034%	56%	54%	55%	54%	55%	**-103%**
Difference from Proposal and **2.0% incr:**	$ 7,555,200	$ 1,593,222	$ (2,736,218)	$ (5,357,555)	$ (7,264,331)	$ (8,541,788)	$ (10,435,262)	**$ (25,186,731)**
Resident UG	4,469,752	1,195,785	(1,089,207)	(2,427,679)	(3,291,092)	(3,927,851)	(4,772,316)	**(9,842,608)** 39%
	59%	75%	40%	45%	45%	46%	46%	**51%**
WUE	3,085,449	397,437	(1,647,011)	(2,929,877)	(3,973,239)	(4,613,937)	(5,662,946)	**(15,344,123)** 61%
	41%	25%	60%	55%	55%	54%	54%	**49%**
Difference from Proposal and **2.5% incr:**	$ 8,076,083	$ 2,711,762	$ (1,013,023)	$ (2,973,378)	$ (4,229,684)	$ (4,969,980)	$ (6,213,177)	**$ (8,611,396)**
Resident UG	4,752,163	1,757,912	(266,252)	(1,330,743)	(1,920,264)	(2,315,813)	(2,871,911)	**(2,194,907)** 25%
	59%	65%	26%	45%	45%	47%	46%	**48%**
WUE	3,323,921	953,850	(746,771)	(1,642,635)	(2,309,420)	(2,654,167)	(3,341,266)	**(6,416,488)** 75%
	41%	35%	74%	55%	55%	53%	54%	**52%**
Difference from Proposal and **3.0% incr:**	$ 8,596,966	$ 3,835,772	$ 727,065	$ (554,054)	$ (1,135,242)	$ (1,309,984)	$ (1,865,693)	**$ 8,294,830**
Resident UG	5,034,574	2,322,788	564,772	(217,638)	(522,424)	(663,974)	(915,063)	**5,603,035** 68%
	59%	61%	78%	39%	46%	51%	49%	**55%**
WUE	3,562,392	1,512,984	162,293	(336,416)	(612,818)	(646,010)	(950,631)	**2,691,795** 32%
	41%	39%	22%	61%	54%	49%	51%	**45%**
Difference from Proposal and **3.2% incr:**	$ 8,815,737	$ 4,309,487	$ 1,462,960	$ 472,626	$ 182,465	$ 253,928	$ (1,616)	**$ 15,495,587**
Difference from Proposal and **3.5% incr:**	$ 9,117,849	$ 4,965,252	$ 2,484,130	$ 1,900,761	$ 2,019,873	$ 2,439,933	$ 2,610,277	**$ 25,538,073**

3.24

Enrollment Distribution		*Metric Enrollment 34,909*	*SEMP Aspirational w/Online growth*
	FY20	**FY25**	**FY25**
UG Online	12%	12%	22%
UG Campus	74%	74%	62%
Grad Online	5%	5%	7%
Grad Campus	8%	8%	9%
	100%	**100%**	**100%**

Academic Year Tuition $M

Gross	**Net**	**Gross**	**Net**	**Gross**	**Net**
320	204	403	252	405	265
	64%		*63%*		*65%*

SEMP=Strategic Enrollment Management Plan

As an acceleration of growth in online enrollment occurs and shifts the overall enrollment distribution between on campus and online, net tuition revenue and the % of net to gross tuition revenue increases.

Impact of 100 fewer Resident UG Pledge students each year FY21-25
Offset by 100 additional students each year in following categories FY21-FY25 (i.e. no impact to enrollment total)

	Additional Gross Revenue $M FY21-25	**Additional Net Revenue $M FY21-25**
+ 100 Pledge Non-Resident UG	6.7	6.9
+ 100 Pledge WUE UG	2.6	4.2
+ 100 Statewide Resident UG	(1.5)	0.9
+ 100 Online UG	(2.2)	0.7
+ 100 Resident Grad	(0.4)	0.3
+ 100 Non-Resident Grad	4.9	5.2
+ 100 Statewide Resident Grad	(2.1)	0.6
+ 100 Online Grad	(1.7)	0.9

With enrollment shifts from Undergraduate Resident Pledge categories to all other categories, net tuition increases given tuition rate and/or financial aid package differences.

Change in Mix

Enrollment (All Enrolled not ABOR Official view)

	FY20	FY21	FY22	FY23	FY24	FY25
Metric	31,478	32,274	33,070	33,866	34,662	35,461
Change Year-to-Year	405	796	796	796	796	799
SEM w/o Aspirational Growth	31,478	32,504	32,897	33,293	33,782	34,230
Change Year-to-Year	405	1,026	393	396	489	448
SEM w/ Aspirational growth	31,478	32,697	33,588	34,732	36,168	38,193
Change Year-to-Year	405	1,219	891	1,144	1,436	2,025

	2025 Metric = 34,909 HC		SEM w/o Aspirational Growth		SEM w/Aspirational Growth = 37,478 HC		Metrics w/SEM Aspirational Distribution =34,909 HC	
	FY20	FY25	FY20	FY25	FY20	FY25	FY20	FY25
UG Online	12%	12%	12%	15%	12%	22%	12%	22%
UG Campus	74%	74%	74%	70%	74%	62%	74%	62%
Grad Online	5%	5%	5%	5%	5%	7%	5%	7%
Grad Campus	8%	8%	8%	10%	8%	9%	8%	9%
Total	100%	100%	100%	100%	100%	100%	100%	100%

Gross Tuition ($)

	FY20	FY21	FY22	FY23	FY24	FY25
Metric - Base	319,533,959	336,443,712	353,523,326	368,889,407	385,538,676	402,851,248
SEM w/o Aspirational Growth - Base	319,533,959	335,060,896	346,563,922	356,123,079	367,429,636	378,825,029
SEM w/ Aspirational Growth - Base	319,533,959	336,220,029	350,846,163	365,267,113	382,984,171	405,219,681
Metrics using SEM w/ Aspirational Distribution - Base	319,533,959	331,876,001	345,430,275	356,159,309	367,040,590	376,248,849

Net Tuition After FPE ($)

	FY20	FY21	FY22	FY23	FY24	FY25
Metric - Base	203,893,027	212,186,730	221,408,144	231,244,359	241,655,523	252,459,620
SEM w/o Aspirational Growth - Base	203,893,027	212,603,037	218,826,471	225,467,761	233,216,092	240,960,073
SEM w/ Aspirational Growth - Base	203,893,027	213,630,954	222,603,496	233,520,635	246,892,165	264,171,262
Metrics using SEM w/ Aspirational Distribution - Base	203,893,027	210,882,878	219,177,982	227,718,493	236,650,623	245,351,655

Change in Mix			FY20	FY21	FY22	FY23	FY24	FY25	Total FY21 to FY25	FY20	FY21	FY22	FY23	FY24	FY25	Total FY21 to FY25
Ugrad	-100	Pledge - Resident — Change in Tuition		(1,005,636)	(1,029,799)	(1,051,473)	(1,072,486)	(1,093,976)	(5,253,371)		(399,054)	(402,483)	(413,967)	(422,252)	(430,400)	(2,068,157)
		Metric		335,438,076	352,493,527	367,837,934	384,466,190	401,757,271			211,787,675	221,005,660	230,830,392	241,233,271	252,029,220	
		% change		-0.30%	-0.29%	-0.29%	-0.28%	-0.27%	-0.28%		-0.19%	-0.18%	-0.18%	-0.17%	-0.17%	-0.18%
		SEM w/o Aspirational Growth		334,055,260	345,534,123	355,071,607	366,357,149	377,731,052			212,203,983	218,423,987	225,053,794	232,793,840	240,529,673	
		% change		-0.30%	-0.30%	-0.30%	-0.29%	-0.29%	-0.29%		-0.19%	-0.18%	-0.18%	-0.18%	-0.18%	-0.18%
		SEM w/ Aspirational growth		335,214,393	349,816,364	364,215,641	381,911,685	404,125,705			213,231,899	222,201,013	233,106,668	246,469,913	263,740,862	
		% change		-0.30%	-0.29%	-0.29%	-0.28%	-0.27%	-0.29%		-0.19%	-0.18%	-0.18%	-0.17%	-0.16%	-0.18%
	+100	Pledge - Non-Resident — Change in Tuition		1,291,090	1,309,233	1,336,900	1,363,842	1,391,638	6,692,703		1,372,129	1,345,763	1,359,645	1,382,350	1,410,207	6,870,093
		Metric		337,734,802	354,832,559	370,226,307	386,902,518	404,242,886			213,558,858	222,753,907	232,604,004	243,037,872	253,869,826	
		Change from Base		0.38%	0.37%	0.36%	0.35%	0.35%	0.36%		0.65%	0.61%	0.59%	0.57%	0.56%	0.59%
		SEM w/o Aspirational Growth		336,351,986	347,873,155	357,459,979	368,793,478	380,216,667			213,975,166	220,172,233	226,827,406	234,598,442	242,370,279	
		Change from Base		0.39%	0.38%	0.38%	0.37%	0.37%	0.38%		0.65%	0.61%	0.60%	0.59%	0.59%	0.61%
		SEM w/ Aspirational growth		337,511,119	352,155,395	366,604,014	384,348,014	406,611,319			215,003,082	223,949,259	234,880,280	248,274,514	265,581,469	
		Change from Base		0.38%	0.37%	0.37%	0.36%	0.34%	0.36%		0.64%	0.60%	0.58%	0.56%	0.53%	0.58%
	+100	Pledge - WUE — Change in Tuition		507,457	517,569	527,763	538,350	549,117	2,640,256		820,267	833,556	847,233	864,150	881,762	4,246,968
		Metric		336,951,169	354,040,895	369,417,169	386,077,026	403,400,365			213,006,996	222,241,699	232,091,592	242,519,673	253,341,382	
		Change from Base		0.15%	0.15%	0.14%	0.14%	0.14%	0.14%		0.39%	0.38%	0.37%	0.36%	0.35%	0.37%
		SEM w/o Aspirational Growth		335,568,353	347,081,491	356,650,842	367,967,986	379,374,146			213,423,304	219,660,026	226,314,995	234,080,242	241,841,835	
		Change from Base		0.15%	0.15%	0.15%	0.15%	0.14%	0.15%		0.39%	0.38%	0.38%	0.37%	0.37%	0.38%
		SEM w/ Aspirational growth		336,727,486	351,363,732	365,794,876	383,522,522	405,768,798			214,451,221	223,437,052	234,367,868	247,756,314	265,053,024	
		Change from Base		0.15%	0.15%	0.14%	0.14%	0.14%	0.14%		0.38%	0.37%	0.36%	0.35%	0.33%	0.36%
	+100	Online (Resident & Non-Resident) — Change in Tuition		(417,862)	(430,905)	(440,944)	(450,320)	(460,133)	(2,200,164)		129,830	137,473	136,930	139,659	142,269	686,161
		Metric		336,025,850	353,092,421	368,448,463	385,088,356	402,391,115			212,316,560	221,545,617	231,381,289	241,795,182	252,601,888	
		Change from Base		-0.12%	-0.12%	-0.12%	-0.12%	-0.11%	-0.12%		0.06%	0.06%	0.06%	0.06%	0.06%	0.06%
		SEM w/o Aspirational Growth		334,643,034	346,133,017	355,682,136	366,979,316	378,364,896			212,732,867	218,963,944	225,604,691	233,355,751	241,102,341	
		Change from Base		-0.12%	-0.12%	-0.12%	-0.12%	-0.12%	-0.12%		0.06%	0.06%	0.06%	0.06%	0.06%	0.06%
		SEM w/ Aspirational growth		335,802,167	350,415,257	364,826,170	382,533,851	404,759,548			213,760,784	222,740,970	233,657,565	247,031,824	264,313,531	
		Change from Base		-0.12%	-0.12%	-0.12%	-0.12%	-0.11%	-0.12%		0.06%	0.06%	0.06%	0.06%	0.05%	0.06%

				Gross Tuition ($)							Net Tuition After FPE ($)						
				FY20	FY21	FY22	FY23	FY24	FY25		FY20	FY21	FY22	FY23	FY24	FY25	
			Metric - Base	319,533,959	336,443,712	353,523,326	368,889,407	385,538,676	402,851,248		203,893,027	212,186,730	221,408,144	231,244,359	241,655,523	252,459,620	
			SEM w/o Aspirational Growth - Base	319,533,959	335,060,896	346,563,922	356,123,079	367,429,636	378,825,029		203,893,027	212,603,037	218,826,471	225,467,761	233,216,092	240,960,073	
			SEM w/ Aspirational Growth - Base	319,533,959	336,220,029	350,846,163	365,267,113	382,984,171	405,219,681		203,893,027	213,630,954	222,603,496	233,520,635	246,892,165	264,171,262	
			Metrics using SEM w/ Aspirational Distribution - Base	319,533,959	331,876,001	345,430,275	356,159,309	367,040,590	376,248,849		203,893,027	210,882,878	219,177,982	227,718,493	236,650,623	245,351,655	
	Change in Mix			FY20	FY21	FY22	FY23	FY24	FY25	Total FY21 to FY25	FY20	FY21	FY22	FY23	FY24	FY25	Total FY21 to FY25
	+100	Statewide - Resident	Change in Tuition		(287,447)	(297,132)	(303,969)	(309,779)	(315,702)	(1,514,028)		175,326	184,070	185,147	189,813	194,985	929,341
			Metric		336,156,265	353,226,194	368,585,438	385,228,897	402,535,546			212,362,056	221,592,214	231,429,506	241,845,335	252,654,604	
			Change from Base		-0.09%	-0.08%	-0.08%	-0.08%	-0.08%	-0.08%		0.08%	0.08%	0.08%	0.08%	0.08%	0.08%
			SEM w/o Aspirational Growth		334,773,449	346,266,790	355,819,111	367,119,856	378,509,327			212,778,363	219,010,541	225,652,908	233,405,905	241,155,058	
			Change from Base		-0.09%	-0.09%	-0.09%	-0.08%	-0.08%	-0.08%		0.08%	0.08%	0.08%	0.08%	0.08%	0.08%
			SEM w/ Aspirational growth		335,932,582	350,549,031	364,963,145	382,674,392	404,903,980			213,806,280	222,787,567	233,705,782	247,081,977	264,366,247	
			Change from Base		-0.09%	-0.08%	-0.08%	-0.08%	-0.08%	-0.08%		0.08%	0.08%	0.08%	0.08%	0.07%	0.08%
Grad	+100	Flagstaff - Resident	Change in Tuition		(90,809)	(87,527)	(80,932)	(72,830)	(64,330)	(396,429)		38,144	47,831	49,857	55,486	61,670	252,988
			Metric		336,352,903	353,435,799	368,808,474	385,465,846	402,786,918			212,224,873	221,455,975	231,294,216	241,711,009	252,521,290	
			Change from Base		-0.03%	-0.02%	-0.02%	-0.02%	-0.02%	-0.02%		0.02%	0.02%	0.02%	0.02%	0.02%	0.02%
			SEM w/o Aspirational Growth		334,970,087	346,476,395	356,042,147	367,356,806	378,760,698			212,641,181	218,874,301	225,517,618	233,271,578	241,021,743	
			Change from Base		-0.03%	-0.03%	-0.02%	-0.02%	-0.02%	-0.02%		0.02%	0.02%	0.02%	0.02%	0.03%	0.02%
			SEM w/ Aspirational growth		336,129,220	350,758,636	365,186,181	382,911,341	405,155,351			213,669,097	222,651,327	233,570,492	246,947,651	264,232,933	
			Change from Base		-0.03%	-0.02%	-0.02%	-0.02%	-0.02%	-0.02%		0.02%	0.02%	0.02%	0.02%	0.02%	0.02%
	+100	Flagstaff - Non-Resident	Change in Tuition		943,166	977,751	942,653	983,100	1,023,277	4,869,948		1,002,688	1,041,513	1,021,116	1,057,044	1,093,275	5,215,636
			Metric		337,386,879	354,501,077	369,832,060	386,521,776	403,874,525			213,189,418	222,449,657	232,265,475	242,712,567	253,552,895	
			Change from Base		0.28%	0.28%	0.26%	0.25%	0.25%	0.26%		0.47%	0.47%	0.44%	0.44%	0.43%	0.45%
			SEM w/o Aspirational Growth		336,004,062	347,541,673	357,065,732	368,412,736	379,848,306			213,605,725	219,867,983	226,488,877	234,273,136	242,053,348	
			Change from Base		0.28%	0.28%	0.26%	0.27%	0.27%	0.27%		0.47%	0.48%	0.45%	0.45%	0.45%	0.46%
			SEM w/ Aspirational growth		337,163,196	351,823,914	366,209,766	383,967,271	406,242,958			214,633,642	223,645,009	234,541,751	247,949,209	265,264,537	
			Change from Base		0.28%	0.28%	0.26%	0.26%	0.25%	0.26%		0.47%	0.47%	0.44%	0.43%	0.41%	0.44%
	+100	Online (Resident & Non-Resident)	Change in Tuition		(332,591)	(335,618)	(336,418)	(336,045)	(336,183)	(1,676,855)		154,553	167,887	173,510	182,956	192,447	871,353
			Metric		336,111,121	353,187,708	368,552,989	385,202,631	402,515,065			212,341,282	221,576,031	231,417,869	241,838,478	252,652,067	
			Change from Base		-0.10%	-0.09%	-0.09%	-0.09%	-0.08%	-0.09%		0.07%	0.08%	0.08%	0.08%	0.08%	0.08%
			SEM w/o Aspirational Growth		334,728,305	346,228,304	355,786,661	367,093,591	378,488,846			212,757,590	218,994,358	225,641,272	233,399,048	241,152,520	
			Change from Base		-0.10%	-0.10%	-0.09%	-0.09%	-0.09%	-0.09%		0.07%	0.08%	0.08%	0.08%	0.08%	0.08%
			SEM w/ Aspirational growth		335,887,438	350,510,545	364,930,695	382,648,127	404,883,498			213,785,506	222,771,384	233,694,145	247,075,120	264,363,709	
			Change from Base		-0.10%	-0.10%	-0.09%	-0.09%	-0.08%	-0.09%		0.07%	0.08%	0.07%	0.07%	0.07%	0.07%
	+100	Statewide - Resident	Change in Tuition		(420,063)	(426,422)	(429,671)	(431,623)	(433,489)	(2,141,268)		93,142	105,020	109,513	117,886	126,873	552,434
			Metric		336,023,649	353,096,903	368,459,736	385,107,053	402,417,759			212,279,872	221,513,164	231,353,872	241,773,408	252,586,493	
			Change from Base		-0.12%	-0.12%	-0.12%	-0.11%	-0.11%	-0.12%		0.04%	0.05%	0.05%	0.05%	0.05%	0.05%
			SEM w/o Aspirational Growth		334,640,833	346,137,500	355,693,408	366,998,013	378,391,540			212,696,179	218,931,491	225,577,274	233,333,978	241,086,946	
			Change from Base		-0.13%	-0.12%	-0.12%	-0.12%	-0.11%	-0.12%		0.04%	0.05%	0.05%	0.05%	0.05%	0.05%
			SEM w/ Aspirational growth		335,799,966	350,419,740	364,837,442	382,552,548	404,786,192			213,724,096	222,708,517	233,630,148	247,010,050	264,298,135	
			Change from Base		-0.12%	-0.12%	-0.12%	-0.11%	-0.11%	-0.12%		0.04%	0.05%	0.05%	0.05%	0.05%	0.05%